Climate change beliefs and savings behavior: a macroeconomic perspective

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The uncertain nature of climate change leaves room for diverse beliefs and considerable disagreement. This paper investigates the transitional effects of climate beliefs on the macroeconomy through shifts in savings behavior. I incorporate climate damages into an incomplete-markets model with aggregate risk as a non-stationary shift in the stochastic process for productivity. Beliefs about the transitional effects of climate change may be both imperfect and heterogeneous across households. The anticipation of climate damages incentivizes savings and increases capital supply in the short-run, which attenuates output losses as climate change progresses. Crucially, I find that a higher level of capital disproportionally benefits asset-poor households, decreasing wealth inequality. The accumulation of capital is dampened by heterogeneity in beliefs due to downward pressure on asset returns in general equilibrium. To validate the model, I provide observational and causal evidence on a positive relationship between individual savings and climate change concerns from UK survey data.

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1 Introduction

Climate change is one of the major challenges faced by humanity in the 21st century. The large uncertainty surrounding future climate impacts however leaves room for diverse beliefs and considerable disagreement, both in the scientific community and the overall population[1]. As key determinants of economic decision making, expectations are central to macroeconomic dynamics, which raises the question of how beliefs over climate change shape the macroeconomy–not only today, but also along a transition during which adverse climate events become more frequent.

This paper uncovers the macroeconomic effects of climate beliefs transmitted via adjustments in individual savings and capital accumulation. I incorporate climate change into a standard incomplete markets model as a shift in the probability measure of the aggregate productivity process. In this stochastic framework, realized climate damages are consistent with a range of subjective probability measures, which enables me to isolate the implications of beliefs. Simulated statistics of the non-stationary system quantify how higher concern over climate damages can attenuate output losses by increasing capital in the long run. I further explore the distributional impacts of this 'climate concern effect' and how heterogeneity in income, wealth and beliefs shape aggregate outcomes.

To begin, I establish the relationship between climate beliefs and individual savings choices, both theoretically and empirically. I estimate the effect of stronger concern about climate change on savings decisions using data from the UK household panel study "Understanding Society", controlling for a broad number of demographic indicators and previous exposure to extreme events. To address an omitted variable bias due to heterogeneity in risk or time preferences, I run robustness checks controlling for individual fixed effects. The data shows a robust positive relationship both on the internal and on the external margin: Those who are most concerned about climate change are on average 9.5pp more likely to save. Their reported share of savings relative to income is on average 1.6pp higher than for those less concerned. Running separate estimations for different income percentiles shows that the relative effect of climate beliefs on savings choices is strongest for low income households. To establish a causal relationship, I implement a within-subject vignette design in a specific purpose only survey to elicit hypothetical savings choices under different climate scenarios. I measure a significant average relative increase of 7.6% in marginal savings under a scenario of increasing compared to constant climate impacts.

These empirical findings are consistent with the predictions of a consumption-savings model under incomplete markets, in which climate change enters as an increase in the probability of a low aggregate state–pushing down both average wages and returns. Under partial equilibrium, I characterize the consumption response to a perturbation in climate beliefs analytically. A key driver of this response is the relative effect of the low aggregate state on the marginal value of savings. Under CRRA utility with an intertemporal substitution below 1,

[1] See Cai (2021) for a comprehensive review of uncertainties considered within the climate economics literature. Public opinion research shows differences in views across the global population, see for example the global survey Peoples Climate Vote (United Nations Development Programme and University of Oxford Department of Sociology, 2024). I further document heterogeneity in perceptions and concern over climate change in UK survey data in section 3.

this effect, first, is positive, predicting an increase in savings due to climate concern[2], and, second, decreases with wealth. Credit constrained individuals however do not make any intertemporal decisions and thus do not react at all to an shift in the process of future states. These two competing effects result in a non-monotone relationship between income and the consumption response in the presence of a borrowing limit.

To examine general equilibrium effects, I develop a structural model with idiosyncratic income shocks, a stylized life-cycle structure, incomplete markets and aggregate risk. I make two key adjustments to include climate change and variations in beliefs.First, I introduce temperature as an exogenous trend variable and allow the probability of a low productivity state to depend on temperature, leading to a non-stationary process of aggregate productivity. The implicit time-dependence captures an important and distinctive feature of climate change, as impacts are projected to worsen over the coming century. Second, I allow agents to have an incorrect prior belief over the relationship between temperature increase and productivity. Dispersion in priors introduces an additional dimension of heterogeneity. The model is thus able to take seriously the empirically documented disagreement over climate impacts and allows an evaluation of its impact on the macroeconomy.

An important feature of my model is the purely stochastic impact of climate change, which deviates from the more standard model of deterministic impacts in the climate-economic literature, as this formulation allows heterogeneous beliefs to be consistent with observations. Note that the change to probabilities still decreases *mean* productivity. Agents use Bayesian updating following realized aggregate states, so that beliefs converge to the truth in the long run. In particular, my results do not hinge on strong assumptions of non-rationality, but simply on inaccurate prior beliefs.

I simulate the economy for a large ensemble of draws from the non-stationary productivity process and obtain interpretable results by considering key summary statistics of the resulting equilibrium dynamics. The case of homogenous and accurate beliefs over climate change impacts serves as a baseline specification. In a first step, I draw comparisons to alternative specifications with still homogenous, but lower initial concern over climate change impacts. Finally, comparisons across different mean preserving spreads in initial concern identifies the aggregate effects of the observed disagreement in climate change beliefs.

The baseline case of homogenous, accurate beliefs shows the relevance of expectations over long-run trends for aggregate outcomes during the transition. Capital initially increases on average due to precautionary and consumption smoothing behavior, before then decreasing to a lower level in the long run, as mean productivity has permanently decreased. If instead the population believes there is only a small chance of productivity being negatively affected, capital decreases as aggregate shocks become more frequent, exacerbating the negative impacts of climate change. The effect first accumulates, but diminishes after about 25 periods due to Bayesian updating. The net present value of output is 12% lower in an economy which believes there is only a 10% chance of climate change leading to productivity damages. Introducing disagreement has a smaller, though more persistent effect on aggregate outcomes.

[2]The effect of higher depreciation rates or stranded assets on savings choices similarly boils down to the relative strength of income and substitution effects. Introducing these as possible consequences of climate change thus does not affect the qualitative predictions of the model.

For a high level of variance, even after 50 years, average capital is 0.3% lower than under homogeneous beliefs.

Looking beyond aggregates into the distributional effects, I find that the 'climate concern' effect decreases wealth inequality in the short run. As a rise in capital increases wages, but decreases returns, accurate beliefs benefit in particular asset poor agents who rely on labor income. Under additional heterogeneity from dispersed beliefs, there is a mechanical divergence between asset holdings of agents with differing beliefs, due to the different savings incentives under a variation in priors. General equilibrium effects lead to an additional shortfall in asset holdings of relatively unconcerned agents: since the latter save more due to climate concern, their presence pushes down the interest rate, which deincentivizes savings for all. Nevertheless, unconcerned poor agents benefit from higher average beliefs, due to the positive effect of capital accumulation on wages.

My model can accommodate agents who are completely ignorant over climate change and thus do not learn and permanently undersave. This leads to a permanent divergence between asset holdings of ignorant agents and anyone who think there is some possibility for impacts of climate change, even if small. An economy which is homogenously ignorant suffers permanent output losses due to lack of capital, beyond physical damages.

An examination of the micro-level behavior shows that higher climate concern increases savings in particular as temperatures increase. Consistent with the empirical evidence, responses to beliefs are higher for poor, low-income and retired agents who have a high relative marginal value for additional values in low productivity states. The forecasting rule for capital plays an important role: if higher concern does not affect expectations over capital dynamics, savings responses are higher, as agents do not account for the positive feedback on capital accumulation and thus expect more severe contractions in output. On the other hand, if agents expect capital to be static, i.e. not affected by productivity shocks, their response to higher climate concern is a lot lower.

Both the cross-sectional heterogeneity and the forecasting rule also matter on aggregate. I compare my baseline results with a representative agent economy, in which climate concern generates a positive, but much smaller effect on capital accumulation. In particular, heterogeneity is necessary to generate the short run increase in capital. Static expectations also attenuate capital accumulation, while an updated forecasting rule amplifies the effect slightly.

In sum, the model uncovers the aggregate and distributional implications of inaccurate and dispersed beliefs over a non-stationary, aggregate shift, transmitted via the savings channel. The macroeconomic predictions particularly emphasize the social value of savings, which on aggregate mitigate the negative impacts along the climate transition by providing a capital buffer.

Solving for individual choices in the general equilibrium model requires a forecasting rule for capital. The model's non-stationary nature necessitates a novel solution method. I extend the algorithm proposed in the seminal work by Krusell and Smith (1998) to approximate a self-justified equilibrium. Estimating a forecasting rule on simulated data from a non-stationary model becomes computationally feasible due to a novel stratification procedure, which matches exactly the theoretical mean and variance. I compare the resulting rule and its macroeoconomic implications with an alternative approach assuming adaptive expectations and varying degrees of memory decay. The general model is applicable to a broad range of macroeconomic questions on the interplay between agent heterogeneity, dynamic trends and beliefs. Other highly relevant examples on uncertain structural shifts include the rise of AI or the fertility decline.

Related literature My work draws on and contributes to several strands of literature, mostly in macroeconomics and environmental economics, but also in finance and computational methods.

There is a vast interest in the macroeconomic implications of climate change, often analyzed within Integrated Assessment frameworks. Rather than level effects, I model climate impacts as shifts in the stochastic process, and in doing so assume both higher damages and higher volatility in output. This is consistent with the large uncertainties around climate change, emphasized for example by Cai (2021) and made tractable in work including Golosov et al. (2014), Cai and Lontzek (2019) and Brock and Hansen (2018). The role of capital accumulation within integrated climate economic models in particular has been examined by Barrage (2018) and Fankhauser and Tol (2005). I avoid taking a stance on socially optimal outcomes and instead employ a bottom-up approach to assess the general equilibrium effects of climate beliefs in a decentralized economy. In my model, uninsurable risks caused by idiosyncratic shocks are a key driver of capital accumulation due to climate concern, a channel that is excluded in any representative agent treatment.

The recent work on the macroeconomic implications of climate change anticipation by Bilal and Rossi-Hansberg (2023) similarly examines the aggregate effects of individual choices. I complement this strand of research by exploring specifically the role of expectations over the uncertain climate transition, allowing on variation and heterogeneity I specifically focus on the uncertainty surrounding climate change. In particular, that allows for the consideration of disagreement. Beliefs over disaster probabilities and their implications for firm level adaptation have been examined by Hong et al. (2023), who I loosely follow in my model of beliefs over climate impacts. An important extension within my model is the non-stationary aggregate shift, a key feature of climate change.

My general equilibrium model builds on the seminal paper by Krusell and Smith (1998), and the extension of their solution algorithm to a non-stationary setting constitutes a computational contribution. I do this by approximating the endogenous law of motion for capital with a temperature-dependent system, which is used by agents within the model to forecast future capital, and iterate until convergence to a self-justified dynamic equilibrium. My work complements recently developed low dimensional perturbation method, see Bilal (2023) and Auclert et al. (2021). Established linear approximations are not able to capture the precautionary motives in reactions to heightened uncertainty present in my model. Furthermore, perturbation methods, even of higher order, are inherently local, and thus not suitable for the large structural shift considered within my model. Efforts to approximate rational expectations equilibria within heterogeneous agent models have recently been criticized by Moll (2024), who instead advocates for adaptive updating over the dynamics of capital. I address this critique by implementing an adaptive forecasting rule with varying degrees of memory decay in a robustness check.

Diagreement between market participants has been widely analyzed in the finance literature, often focusing on risk-sharing between optimists and pessimists under anticipation of future risks. Chen et al. (2012) reports comparative statics on risk premia after disasters and during normal times. Examples of specific climate change related applications are the works by Bakkensen et al. (2023) and Lontzek et al. (2024), who differentiate asset types either by their riskiness and carbon footprint, respectively. In contrast, I consider the demand for a singular type of asset, which can only be used in production, and characterize the consumption response to belief shifts analogous to Farhi et al. (2022). By simulating the economy over time, I am able to compare the effects in ex ante pricing to the impact of disagreement along the transition and assess the welfare effects of inaccurate beliefs on an individual, distributional and aggregate level.

Structure of the paper I begin by setting up a stylized consumption-savings model with exogenous prices in section 2, which yields theoretical predictions on the savings choice under varying beliefs over climate impacts. Section 3 provides observational and causal empirical evidence from UK surveys on the relationship between climate beliefs and savings choices. In section 4, the model is extended to allow for endogenous prices: individual savings pin down capital. This section also explains the algorithm used to construct a boundedly rational capital forecast. Predictions on the macroeconomic effects of climate change beliefs based on model simulations are reported in 5. I further discuss the underlying mechanisms and examine the robustness with respect to modeling assumptions. Section 6 concludes.

2 Consumption-savings decisions in partial equilibrium

I first introduce a very general consumption-savings model in which consumers face both idiosyncratic and aggregate uncertainty. By abstracting from endogenity of future wages and returns, this set-up allows an analytical partial equilibrium characterization of the consumption response to changes in beliefs over the aggregate process. A decomposition of the response illustrates its determinants, based on the decision makers current idiosyncratic state.

2.1. The consumption-savings problem

Each period t, all individual agents, indexed by i, draw an idiosyncratic state ϕ_{it} from a finite set Φ. A state ϕ may represent skills or demographics and can also include death to allow for life-cycle effects. The process ϕ_{it} is allowed to be correlated over time. The aggregate economy is either in a high or low productivity state, which is indicated by the random variable $\zeta_t \in Z = \{\zeta^L, \zeta^H\}$ with $\zeta^L < \zeta^H$. In a given period, the probability of $\zeta_t = \zeta^L$ is given by p_t, and we assume that ζ_t and ϕ_{it} are independent for all $i,\ t$.

Aggregate shocks affect the productivity of a representative firm. Asset returns $R(\zeta) > 0$ and average wages $w(\zeta) > 0$ only depend on the current aggregate state. In particular, prices are unaffected by asset choices, a key assumption that is relaxed in section 4. Both returns and average wages are lower in the low state, but in the empirically relevant case of partial capital depreciation, the relative drop in wages is higher than for returns, i.e.

$$\frac{w(\zeta^L)}{w(\zeta^H)} < \frac{R(\zeta^L)}{R(\zeta^H)}.$$

While everyone is subject to the same rate of return, labor income varies by idiosyncratic type and is given by

$$y(\zeta, \phi) = w(\zeta)e(\phi)$$

where e is some function of the idiosyncratic state. I assume $e(\phi) \geq \underline{e} > 0$ for all ϕ, so that income is always above a minimal, positive threshold. Markets are incomplete. It is only possible to save a non-negative amount in assets, leading to the budget constraint

$$c_{it} + a_{it+1} = y(\zeta_t, \phi_{it}) + R(\zeta_t)a_{it} =: m_{it}, \quad a_{it+1} \geq 0,$$

where m_{it} denotes current cash-on-hand. I allow for heterogeneity in initial asset holdings a_{i0} and individual state ϕ_{i0}. I write $\theta_{it} = (\zeta_t, \phi_{it})$ for the overall state relevant for household i and $\theta^{it} = (\theta_{i0}, \dots, \theta_{it})$ for the history of states up to time t.

An agent i chooses consumption to maximize expected utility over their life-time

$$\max_{c_{it}(\theta^{it}{}_{\theta,\ t}} \mathbb{E}\left[\sum_{t=0}^{\infty} \beta^t u(c_{it})\right].$$

Aggregate shocks and climate change Economic impacts of climate change to the macroeconomy are often modeled as deterministic damages to productivity, see, e.g., Nordhaus (2008), Cai and Lontzek (2019), Golosov et al. (2014)[3]. Here, I assume instead that concern about the economic impacts of climate change increases the perceived probability of the low productivity state, i.e. $dp_t > 0$ for at least one t, which implicitly captures a decrease in expected productivity. The shift from deterministic to stochastic climate impacts is crucial to generate a persistent deviation of accurate beliefs in the dynamic setting of section 4 without imposing extensive irrationality, as realized climate impacts are possible under a range of different beliefs. Importantly, as climate change is a non-stationary process, the effect on p may vary over time. This formulation thus also allows for the case of a decision maker becoming aware of a change before it actually happens, capturing anticipatory effects.

2.2. Cosumption response

I now drop the index i and derive the relative response of initial consumption $d \ln c_0$ to an unanticipated change in probabilities, dp_t for $t \geq 1$. As optimal consumption is always nonzero for standard utility functions, this will never be ill-defined. Focusing on consumption rather than savings has the advantage of facilitating comparisons with the literature, most importantly to the closely related work by Farhi et al. (2022). As initial income is fixed by the

[3]It is sometimes additionally assumed that climate change increases the depreciation rate, for example in Bilal and Rossi-Hansberg (2023). Under CRRA utility with an intertemporal elasticity of substitution below 1, wealth effects dominate substitution effects, so that the consumption response following an increase in the (expected) depreciation rate is non-positive. Including this type of climate impact would thus also increase savings and not change the qualitative implications of my model.

current state, the response of the savings share can be recovered as $da_1/m_0 = -dc_0/m_0 = -d\ln c_0 \cdot c_0/m_0$.

Let $MPS_t = da_{t+1}/dy_t = 1/R_t \cdot da_{t+1}/da_t$ be the marginal propensity to save out of income and $\varepsilon_t = -u(c_t)/(c_t u''(c_t))$ the elasticity of intertemporal substitution, both evaluated at the optimal choices $c_t,\ a_{t+1}$.

Proposition 1 To first order, the relative response of consumption c_0 to a perturbation in the sequence of probabilities dp_t for $t \geq 1$ is given by

$$\frac{dc_0}{c_0} = -MPS_0\varepsilon_0 \sum_{t=0}^{\infty} \left(\sum_{\theta^t} \mathbb{P}^*(\theta^t) \left(\prod_{j=1}^{t} MPS_j(\theta^j) \right) \mathcal{D}_t(\theta^t) \right) dp_{t+1}. \tag{2.1}$$

Here,

$$\mathcal{D}_t(\theta^t) = \frac{\mathbb{E}[V'(a_{t+1},\theta^{t+1})|\zeta_{t+1} = \zeta^L,\ \theta^t] - \mathbb{E}[V'(a_{t+1},\theta^{t+1})|\zeta_{t+1} = \zeta^H,\ \theta^t]}{\mathbb{E}[V'(a_{t+1},\theta^{t+1})|\theta^t]}$$

is the expected marginal value of holding an extra unit of assets in the low versus high aggregate state relative to the average expected marginal value of wealth, conditional on the previous idiosyncratic state, and

$$\mathbb{P}^*(\theta^t|\theta^{t-1}) = \mathbb{P}(\theta^t|\theta^{t-1})\frac{V'(a_t,\theta^t)}{\mathbb{E}[V'(a_t,\theta^t)]}, \quad \mathbb{P}^*(\theta^t|\theta^{t-1}) = \mathbb{P}^*(\theta^t|\theta^{t-1})\mathbb{P}^*(\theta^{t-1})$$

is the risk-adjusted probability of state θ^t.

In the case of CRRA utility, $\mathcal{D}_t(\theta^t) > 0$ for all θ^t, so that

$$\frac{d\ln(c_0)}{dp_t} \leq 0 \text{ for all } t \geq 0.$$

The result follows from an application of the implicit function theorem to the Euler equation, see appendix A.1 for a detailed derivation. An analogous result in a slightly different setting is discussed by Farhi et al. (2022). This expression can now be used to disentangle the different channels driving the consumption response and to obtain predictions for heterogeneous reactions in the cross-section of households.

On the margin, the change in beliefs is only relevant for those agents who already make intertemporal decisions, which are those who already engage in savings and satisfy $MPS > 0$. The marginal propensity to save is a measure of how agents trade off between today and the future, with a high value indicating a relatively higher value of future consumption. As expectations over the future states vary, an agent with a high MPS will react stronger compared to one with a low MPS. In the extreme case of $MPS = 0$, the agent would prefer borrowing to consume more today and less in the future, but is constrained by the borrowing limit.

The elasticity of intertemporal substitution ε_0 mediates the consumption response: An agent who is more responsive to changes in relative prices reacts more to substitution effects. Crucially, however, due to the time separability of preferences, the IES coincides with the reciprocal of the coefficient for relative risk aversion. Thus, a change in $\varepsilon(c)$ also effects the marginal value of savings, another relevant statistic for the consumption response.

The key novel aspect of the decomposition is given by $\mathcal{D}_t(\theta^t)$, capturing the marginal value of savings. An increase in the probability of $\zeta_t = \zeta^L$ leads to a decrease of the same size in the probability of $\zeta_t = \zeta^H$. Thus, the direct effect on the expectation of the future marginal value of additional savings is given by dp_t times the difference between the expected marginal values of the low and high state. As the consumption response follows a change in probabilities from a previously optimal choice, what matters is not the marginal value of assets in the low state, but rather how much more an agent values assets in the low versus high state. If the marginal value is high in either case, then the marginal utility of consumption today is also high, as given by the Euler equation, so that the difference matters only relative to the unconditional marginal value of assets in the future. In general, $\mathcal{D}_t(\theta^t)$ could be negative. However, in the standard case of CRRA utility with an IES < 1 and a relatively larger drop in wages than returns, the marginal value of holding assets is higher in the low than in the high state, so that $\mathcal{D}_t(\theta^t)$ is positive[4]. Note further that $\mathcal{D}_t(\theta^t)$ is bounded above, as everyone receives a positive income each period.

Perturbations in dp_t for $t > 1$ lead to a consumption response today only it also affects the choice in period $t-1$. Otherwise, the agent would just reallocate to an earlier period which is inconsistent an optimal decision under no perturbation. Thus, the response can be derived recursively, and future perturbations are weighed by the product over marginal propensities to save from now until then. In particular, a binding borrowing constraint in state θ^j implies $MPS(\theta^j) = 0$, so that any variation dp_{j+i} within that scenario is irrelevant for the consumption choice today.

Finally, for $t > 1$, the agent accounts for the uncertainty over their idiosyncratic state in $t-1$. Those states in which the marginal value of holding extra assets is higher matter relatively more for the consumption response. The contribution of a specific state can be expressed using the risk-adjusted measure of the physical probability, under which high marginal value states are weighted higher. This is analogous to the expression derived by Farhi et al. (2022).

It is now clear that a change in ε_0 leads to counteracting effects: A higher IES, which at first glance suggests a larger response, corresponds to a lower coefficient of relative risk aversion. In that case, the difference in marginal values of savings between bad and good outcomes is lower, so that both $\mathcal{D}_t(\theta^t)$ and the risk adjusted weights of bad states decrease. Quantitatively, the latter effect dominates, so that responses are higher for high coefficients of relative risk aversion.

2.2.1. Hand-to-mouth agents

In this model, the agent chooses whether to save at all: if they would prefer to borrow in the absence of a borrowing constraint, they become hand-to-mouth. For those who do not save in period 0, the multiplier on the borrowing constraint is positive, so that the first order condition implies the inequality

$$u'(c_0^{\max}) > \beta \mathbb{E}[V_1'(0)].$$

[4]This also follows from Flynn et al. (2023): the increase in p_t is decreases the continuation value, so that the consumption response under homothetic preferences is negative.

Here, $c_0^{\max} = y_0 + R_0 a_0$ is their consumption choice, which is the maximal amount they can consume by not saving at all. The inequality captures that they would prefer to consume more but are constrained by the borrowing limit $a \geq 0$. They will start saving following a perturbation dp_1 if and only if

$$\beta \left(\mathbb{E}[V_1'(0)|\zeta^L] - \mathbb{E}[V_1'(0)|\zeta^H] \right) dp_1 > u'(c_0^{\max}) - \beta \mathbb{E}[V_1'(0)]. \tag{2.2}$$

For an infinitesimal change dp_1, condition (2.2) can only be fulfilled for an infinitely large difference between expected marginal values of holding assets in the low versus high state. However, this difference is bounded as agents receive positive income in each period, so that hand-to-mouth agents will not react to the perturbation dp_1. Note that $MPS_0 = 0$ for hand-to-mouth agents, so that equation (2.1) still holds.

In the data presented in section 3, however, climate concern is correlated with whether or not individuals save, not just which amount they save. The model can generate this effect on the extensive margin for non-infinitesimal shifts in probabilities, as the ones introduced in section 4.

2.3. The role of the idiosyncratic state

The decomposition in proposition 1 offers a framework to discuss the relevance of idiosyncratic characteristics and enables us to find predictions on how the consumption response differs in the cross section.

In many macroeconomic models, the intertemporal elasticity of substitution is assumed to be constant across the population. Variation in the marginal propensity to save on the other hand is a key driver of wealth accumulation in macroeconomic heterogeneous agent models. A standard consumption function is concave in current cash on hand, so that the marginal propensity to save increases in both income and wealth. The MPS is further affected by expectations over future earnings: Agents with low cash on hand in the first period would like smooth consumption by borrowing especially if they expect their income in the next period to be sufficiently high. When modeling income dynamics with a standard AR(1) process, those individuals with the lowest earnings today are the ones who expect a *relative* increase in their earnings, even under high persistence. In the empirically plausible case where low income furthermore correlates with low wealth, there is a bunching of low income agents with $MPS \approx 0$ close to the borrowing constraint.

Income and asset holdings are also sources of heterogeneity in $\mathcal{D}(\theta^t)$. For a given level of earnings, the difference drops as asset holdings a_0 rise, due to the convexity of marginal utility. Similarly, the difference is also higher for low earners if the income process is indepent over time. The monotonicity in labor earnings however no longer obtains in the empirically relevant case of a persistent, mean reverting income process. Whether the value $\mathcal{D}(\theta^t)$ is higher for low or high earners then also depends on the asset holdings. Those who currently have both low income and are also asset poor will be particularly bad off in the low aggregate state, so that $\mathcal{D}(\theta^t)$ remains higher for low compared to high income individuals who both hold low assets. As asset holdings increase and the difference $\mathcal{D}(\theta^t)$ drops, it however does so faster for low than for high earning agents. Due to mean reversion, high earners are more likely to have lower income in the future relative to today. In those cases, the difference in the marginal value of savings between the low and high state is higher. For high asset holdings, this channel dominates, leading to higher values of $\mathcal{D}(\theta^t)$ for high income individuals.

In summary, the multiple channels through which the idiosyncratic state affects the consumption response may counteract each other. The interaction between the marginal propensity to save and the difference in marginal values of savings is crucial: While poor, low income households are the ones who gain the most from having more savings in low productivity states of the world, they may not react at all due to their small marginal propensity to save. It is a quantitative question to see which effect dominates.

Appendix A.2 reports quantitative results from a partial equilibrium version of the calibrated model in section 4, which show a non-monotone relationship between the savings response and the idiosyncratic state.

3 Empirical evidence

The previous section suggests a positive effect of climate change concern on individual savings in a stylized framework, motivating an empirical examination of the relationship between beliefs and savings. In particular, the theoretically derived dependence of the consumption response on the *MPS* raises the question of whether there is an extensive margin effect of climate change beliefs on savings.

The goal of this section is thus to estimate an equation of the type

$$\mathfrak{s}_{it} = f(\iota_{it}, X_{it}; \varepsilon_{it}). \tag{3.1}$$

Here, $\mathfrak{s}_{it}$ is some savings indicator, ι_{it} is a measure of concern about climate change and X_{it} is a vector of controls, including personal income y_{it}.

This section draws on two different data sources, the UK Understanding Society survey and a novel, specific purpose online questionnaire. I consider three different savings indicators: whether or not to save, how much to save relative to income, and how much to save out of an additional transfer.

3.1. Observational evidence

3.1.1. Data and measurement

The data is taken from the UK Longitudinal Household Study *Understanding Society*, Institute for Social and Economic Research University of Essex (2022). Individuals in participating households are interviewed once a year, either face-to-face or through a self-completion online survey, yielding an unbalanced panel. The study started with 40000 households in the first wave in 2009. There are now 14 waves available, with the last one collected in 2022-23. The data can be acquired via the UK Data Service after application. A special access license is necessary to use locational data.

Beliefs about climate change Questions about climate change beliefs were asked in waves 1 (2009-10), 4 (2012-13) and 10 (2018-19). Unfortunately, the mode of response was changed for some questions from wave 1 to 4. The main specification uses only data from waves 4 and 10. In particular, the analysis does not include waves of the survey that were conducted during the COVID pandemic. In the benchmark specification, the sample is made up of around 65000 observations across the two waves.

Savings data Questions related to savings are asked in all even waves of the survey. Respondents are asked *Do you save any amount of your income?*, to which they can answer 'yes' or 'no', and *About how much on average do you personally manage to save a month?*, which asks them to enter a non-negative GBP amount. These two questions allow us to analyze savings behavior both on the extensive and intensive margin. Savers are also asked if their savings are mainly planned to be long-term or short-term, neither, or both equally. This indication is used for an additional analysis.

Any responses with average monthly savings in excess of income are excluded, and the data is winsorized at the 99th percentile. I obtain relative savings s_{it} by dividing the amount reported by income.

Income data For my baseline analysis, I use the derived total net personal income variable as y_{it}, which is net of taxes on earnings and national insurance contributions but without any further deductions. All income is converted to a monthly basis. Responses with negative incomes are dropped - this only happends due to self-employment reported losses. Again, the data is winsorized at the 99th percentile. Income data is collected each wave.

Location The special access version of the UKHLS survey includes the current place of residence for each respondent in England and Wales down to Lower layer Super Output Areas (LSOAs) according to the Census 2021 data.

Controls Further variables from the survey that are included as controls in the vector X_{it} are level of education, ten-year age bracket, number of children and a year dummy.

Flood and geographical data The Environment Agency's Recorded Flood Outlines data collects dates and geographic informations of historic flooding from rivers, the sea, groundwater and surface water. The Open Geography portal offers boundary set files for all LSOAs.

3.1.2. Measurement

Measuring concern about climate change The questionnaire in waves 4 and 10 includes five questions which I use to measure concern about climate change impacts on the UK. Participants were asked to answer 'yes' or 'no' whether they believed in the statement *People in the UK will be affected by climate change in the next 30 (200) years* and to state the extent to which they agree or disagree with the statements *If things continue on their current course, we will soon experience a major environmental disaster*; *The so-called 'environmental crisis' facing*

	Overall	Wave 1	Wave 2
Mean	0.7181	0.6859	0.7570
SD	0.2162	0.2201	0.2048

Table 1: Descriptive statistics on the concern index

humanity has been greatly exaggerated; and *The effects of climate change are too far in the future to really worry me*. The scale offered five possible response: ’strongly (dis)agree’, ’tend to (dis)agree’ and ’neither agree nor disagree’.

To obtain an aggregate index on the belief about climate change, I first normalize all responses to numerical values within the unit interval so that a higher value correspond to higher concern. The resulting variables are positively correlated, though not very highly, see appendix C.2. These auxiliary indices are then aggregated into a single index. In the baseline, my measure will simply be the mean of all normalized responses. Robustness checks with alternative definitions show that the key results are not very sensitive to the exact weighting of variables.

Further questions ask about their belief over individual responsibility for climate change and their environmental habits. Similarly obtained indices based on those responses are included as controls in some robustness checks. All questions as well as the definition of the indices are reported in appendix C.

Measuring exposure There is some evidence that climate change beliefs may be affected by personal exposure, examined for example by Howe et al. (2019) and Rüttenauer (2024). It seems reasonable to expect that those individuals who are individually particularly exposed to climate change, for example due to their place of residence, would also save more to insure themselves.

This poses a challenge for my identification, as I want to examine savings as a response to the aggregate risks of climate change. Controlling for exposure would ensure that my results are not driven by individually highly exposed respondents.

I focus on exposure to floods, which are frequent environmental events in the UK, using the methodology of Rüttenauer (2024) to match historic floods to LSOAs. A respondent is flagged as exposed if their place of residence experienced a flood within the past 2 years which affected more than 3% of the are within a one mile radius of the population-weighted centroid of their respective LSOA. This measure has been shown to have a positive effect on climate change beliefs by Rüttenauer (2024).

3.1.3. Descriptive Statistics

Table 1 collects means and standard deviations of the belief index in each wave and overall. The autocorrelation of this index is $\rho = 0.5268$. Importantly, the index is not perfectly persistent, so that we can exploit the time variation of beliefs within one individual.

3.1.4. Empirical strategy

My baseline regression to estimate the relationship between climate change concern and savings is a simple linear specification for $\mathfrak{s}_{it}$ which may either be the probability of saving $\mathbb{P}(s_{it} > 0)$ or the savings share s_{it}:

$$\mathfrak{s}_{it} = \alpha\iota_{it} + \gamma \ln(y_{it}) + \beta X_{it} + \varepsilon_{it}.$$

The value of $\alpha(\mathfrak{s})$ can then be interpreted as the effect of being maximally concerned versus not at all on the probability of saving or the savings share, respectively. As the considered savings variables are restricted, I also specify non-linear models

$$\mathfrak{s}_{it} = G(\alpha\iota_{it} + \gamma \ln(y_{it}) + \beta X_{it} + \varepsilon_{it}).$$

which are solved by maximum likelihood estimation. G is taken to be the logistic function for the binary indicator and the maximum function $G(x) = \max\{x, 0\}$ for the savings share, i.e. a Tobit regression.

Individual fixed effects A key concern for my identification is the role of unobserved idiosyncratic characteristics relevant for both savings and climate beliefs, for example preferences. A particularly patient or risk averse individual would be expected to save more, and also to be more concerned about climate change. As there are two waves which include both savings and climate belief questions, I can control for individual fixed effects and examine within respondent variation. This isolates the effect of climate change concern from those of variables that are constant over the life-cycle, a common assumption for preferences. As the restriction leads to a significant loss in variation, I only control for the log of income when including individual fixed effects.

Distributional heterogeneity The analytical derivations in section 2 suggest a relationship between the savings response to climate change beliefs and the idiosyncratic state. I examine this channel in the data by running my baseline regression separately for each of the five quintiles.

3.1.5. Results

Tables 2 and 3 report the main results of the empirical estimation on the extensive and the intensive margin, respectively.

Both OLS and a Logit model estimate that the probability to save is 9.5 percentage points higher for respondents with maximum versus those with no concern, and that this estimate is significant at the 1% level. Controlling for the flood-based exposure measure does not have a major effect; the coefficient is insignificant. As expected, including individual fixed effects makes a larger difference. Still, the probability to save is estimated to be 4.4 percentage point higher for those with high climate beliefs. Importantly, this specification also controls for the exposure measure. Under area fixed effects, the estimate of 8.6 percentage points is again closer to the unconditional OLS estimate.

	Probability to save $\mathbb{P}(s > 0)$				
	(1)	(2)	(3)	(4)	(5)
CC concern index ι	0.095***	0.094***	0.095***	0.044**	0.086***
	(0.010)	(0.010)	(0.010)	(0.020)	(0.015)
Wave FE	✓	✓	✓		✓
Income control	✓	✓	✓	✓	✓
Additional controls	✓	✓	✓		
Ind FE				✓	
Exposure control		✓	✓	✓	
Area FE					✓
Observations	64,847	64,847	64,847	44,111	44,094

$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table 2: Marginal effect of ι on the probability to save. (1) and (2) are the baseline OLS specifications, where (2) controls for flood exposure. (3) reports the average marginal effect in a Logit model. (4) includes individual fixed effects. (5) includes area fixed effects.

Table 3 reports the estimated marginal effects of the belief index on the relative amount of savings. Again, the exposure flag plays only a small role. Both OLS specifications estimate an effect on the savings rate of 1.6 percentage points. Under a Tobit model, the average marginal effect is even estimated to be 5.1pp. Including individual fixed effects here makes the estimate insignificant. The specification with area fixed effects is at 1.2pp again close to the OLS estimate.

3.1.6. Distributional analysis

The estimated marginal effects from separate regressions for each income quintile are reported in table 4.

Restricting the sample to the lowest income quintile leads to strong effects: In this subsample, respondents with a maximum concern index are 10.7 percentage points more likely to save as estimated with the standard OLS specification. On the intensive margin, the OLS model estimates a 3.1 percentage point increase of the savings rate, whereas the Tobit model estimates even 14.3 pp. The stark difference between the TOBIT and the OLS estimate is particularly pronounced in this subsample, which supports the theory developed in section 2: conditional on saving, the poor react more to additional aggregate risks.

There is no clear monotone downwards trend in the effect as income increases. The effects are similarly large in the fourth quintile. However, the analysis does show that when restricting the sample to the top income quintile, the effect sizes are significantly lower. The

	Savings share s_{it}				
	(1)	(2)	(3)	(4)	(5)
CC concern index ι	0.016***	0.016***	0.051***	−0.002	0.012***
	(0.003)	(0.003)	(0.006)	(0.005)	(0.004)
Wave FE	✓	✓	✓		✓
Income control	✓	✓	✓	✓	✓
Additional controls	✓	✓	✓		
Ind FE				✓	
Exposure control		✓	✓	✓	
Area FE					✓
Observations	60,645	60,645	60,645	41,192	41,175

Table 3: Marginal effect of ι on the share of savings relative to income. (1) and (2) are the baseline OLS specifications, where (2) controls for flood exposure. (3) reports the average marginal effect in a Tobit model. (4) includes individual fixed effects. (5) includes area fixed effects.

OLS estimate for the intensive margin becomes insignificant. Again, the drop in estimates is consistent with the theoretical predictions, suggesting that high income individuals suffer less from bad aggregate shocks.

3.1.7. Limitations of panel survey data

The results above suggest a relevant connection between climate change concern and savings. However, as this large scale survey is not specifically designed to tease out this relationship, there are some natural limitations when interpreting the previous results.

One caveat of the broad survey questionnaire is that it gives no insights about the relevant concerns of respondents related to climate change. My interpretation within the models of section 2 and 4 considers climate change as an aggregate risk.

Furthermore, there are likely some concerns over interpretation of individual fixed effects over a timespan of five years. The specifications only include income fixed effects due to low variation, but other drivers may also affect the results, such as the overall increase in concern or unreported wealth transfers. As the Understanding Society survey is quite long, small changes in reported climate concern between the two waves may also be due to lack of attention rather than an actual change in beliefs. Finally, while I can control for one specific type of exposure, substantial flooding in respondents' area, there are many other individual characteristics that may affect exposure as well as savings, e.g. health conditions.

		Q1	Q2	Q3	Q4	Q5
$\mathbb{P}(s_{it} > 0)$	OLS	0.107	0.099	0.066	0.108	0.058
		(0.021)	(0.022)	(0.022)	(0.022)	(0.022)
	Logit	0.109	0.100	0.066	0.108	0.057
		(0.021)	(0.022)	(0.022)	(0.022)	(0.022)
s_{it}	OLS	0.031	0.013	0.014	0.015	0.006
		(0.008)	(0.005)	(0.005)	(0.005)	(0.006)
	Tobit	0.143	0.058	0.036	0.041	0.019
		(0.028)	(0.014)	(0.011)	(0.009)	(0.009)
Observations		13909	13908	13908	13907	13907

Table 4: Marginal effects estimates of concern index on savings variables for subsamples along the income distribution quintiles. Controlling for wave fixed effects, income, exposure, and additional controls.

3.2. Causal evidence from a novel survey

I supplement my empirical motivation with results from a special purpose survey, designed to test for the effect of climate change beliefs on savings behavior. This additional survey allows a close connection between the model predictions and empirical evidence.

3.2.1. Survey design

The savings response derived in section 2 is driven by the increase in perceived likelihood of future low productivity states. While this is a common and tractable way to model climate impacts, they are in reality multifaceted. Two individuals who both feel highly concerned about climate change may have very different mechanisms in mind which will affect their anticipative choices.

When varying beliefs over climate change impacts, the survey aims to strike the balance between somewhat controlling the variation in interpretation without fixing an exact damage mechanism. In particular, the goal is not to understand how individuals react to changes in the stochastic productivity process, but rather whether modeling climate change as such can rationalize actual observed behavior.

The next two paragraphs explain the survey design. Exact instructions can be found in appendix D.3.

Savings choice The key part of the survey are two savings choices to assess the role of beliefs in a within-subject design. Participants are asked to decide how much of a hypothetical payment of 5000 GBP they would save and spend, respectively, taking one of two counterfactual scenarios as given. Before they see these scenarios, they are shown brief definitions of spending and saving, taken from Andre et al. (2025).

The two scenarios are picked as one in which climate change increases shocks to the UK, and one in which it does not. They are presented in randomized order.

Scenario 1:

> Assume that currently, climate-related events with significant negative consequences to the UK happen on average once every 7 years, and that the average frequency **increases** due to climate change. Assume that these events will happen, on average, twice as often by 2040 (once every 3.5 years) and more than three times as often by 2100 (once every other year).

Scenario 2:

> Assume that currently, climate-related events with significant negative consequences to the UK happen on average once every 7 years, and that the average frequency **will not change until 2100.**

The phrasing specifically varies the frequency of impacts of climate change on the UK, rather than whether or not climate change happens. Furthermore, participants are reminded that climate-related damages to the UK are possible both with and without climate change. Due to my specific focus on uncertainty and economic impacts, the wording deviates from complementary work such as Georgarakos et al. (2025), in which scenarios are differentiated instead by distinct levels of temperature increase.

The frequencies are consistent with the calibration of my model in section 4. As I want to find out how respondents think of climate change, rather than shifts to productivity, I do not specify the kind or extent of impacts.

Using a hypothetical payment identifies results as marginal responses, complementing the evidence of section 3 in which respondents were only asked about overall savings. Asking about the choice out of an additional transfer has the benefit of avoiding anchoring, and makes the savings choice more salient. Furthermore, this introduces a third indicator $\mathfrak{s}_i = ms_i$, marginal savings out of a transfer. This is particularly important to understand behavior of credit constrained agents, as for it cannot be identified whether differences in reported savings are due to A large hypothetical payment of 5000 GBP is chosen to incentivize intertemporal decision making and suppress quick-fixing behavior to low income shocks, see the recent evidence by Andre et al. (2025).

Closing questionnaire After the savings choice, participants are asked to pick from a list of options through which specific mechanisms they expect climate change to affect the UK. The list is reported within the instructions in D.3. The survey closes with questions on current savings behavior, overall beliefs over climate change impacts, and previous financial losses attributed to climate change.

3.2.2. Sample

To ensure comparability with the results from the panel survey, I only consider UK residents, but do not restrict their nationality. Participants are recruited via the platform Prolific and paid 90 pence for their responses. To collect additional demographic characteristics, the pool of potential participants is further restricted to those who have answered questions on their

	Sample		
	(1)	(2)	(3)
Δs	0.0763***	0.0588*	0.0833***
	(0.0180)	(0.0311)	(0.0212)
Observations	543	99	444

*p <0.1; **p <0.05; ***p <0.01

Table 5: Relative difference between savings choice in changing and constant scenario. (1) is the full sample. (2) is the subsample of those who responded Yes to the question 'Have you so far experienced any financial losses that you believe can be attributed to climate change?'. (3) is the subsample of those who expect aggregate effects of climate change to the UK.

age, individual and household income bracket, nationality, ethnicity and whether or not they have children. 20 participants are recruited for a pilot study, which is used to estimate the necessary number of participants within a power analysis, see appendix D.1, and to adjust the payment. The main sample consists of 543 responses, all collected in the afternoon of Saturday, October 11th 2025.

3.2.3. Empirical strategy

The key statistic of interest is the relative change in savings when confronted with the increasing versus constant climate impacts, which is observed for each individual participants. Focusing on relative rather than absolute numbers better isolates the effect of changing scenarios and prevents results from being driven by savers. Under the constant and the changing scenario, respectively, only 13 and 7 out of 543 participants in the final sample do not save, with the latter group being a subset of the former.

Below, I report sample averages over Δs for a range of different subsamples. Due to the limited number of observations, coefficients on additional controls are usually insignificant, but the comparison still offers interesting qualitative results.

3.2.4. Results

Table 5 reports the average results for three different samples. For the full sample, savings increase on average by 7.6%. The additional questionnaire allows me to consider two further subsamples. Column (2) shows the average relative change in the group of those who indicate that they have already experienced any financial losses which they believe can be attributed to climate change. In this group, the savings response is lower than in the full sample. The share of people who increase their savings however is higher. Finally, if restricting to the group of respondents who report to expect significant adverse effects to the aggregate UK economy, the estimate rises only slightly. This suggests that participants did respond based on the presented scenarios, even when not actually believing them.

We can now again consider heterogeneity in the savings responses across different characteristics. In table 6, I report first the results for a sample split at different income levels,

	Income			
	low	medium	high	NA
Δs	0.1002^{***}	0.0715^{**}	0.0534	0.0525
	(0.0305)	(0.0311)	(0.0417)	(0.0362)
Observations	178	230	81	54

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

(a) Effect size based on yearly personal income bracket (self-reported). 'Low' denotes up to 19,999 GBP, 'medium' between 20,000 − 39,999 GBP, and 'high' above 40,000 GBP.

	Save		Savings share		
	No	Yes	low	medium	high
Δs	0.0906	0.0728^{***}	0.0756^{**}	0.0946^{***}	0.0608^{***}
	(0.0614)	(0.0165)	(0.0313)	(0.0337)	(0.0221)
Observations	109	434	165	126	98

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

(b) Effect size based on savings behavior. Shares are based on the question 'What percentage of your annual income do you save' and grouped as: 'low' $\leq$ 10%, 'medium' > 10%, $\leq$ 25%, 'high' > 25%, $\leq$ 50%. The group of 45 participants who indicated a savings share higher than 50% are not presented, as the response indicates low attention.

Table 6: Relative savings increases based on income and personal savings behavior.

and second, splits based on reported overall savings behavior. As in the panel evidence and the theoretical model, low income households react the strongest in the online survey: they increase their savings by 10% on average.

Furthermore, the point estimate is higher for non-savers than for savers, supporting the theoretical argument that a low marginal propensity to save is correlated with higher expected marginal value of additional savings as shocks become more frequent. Note however that the estimate within the group of participants who state that they do not save is not significant. The participants who indicated that they currently save part of their income were further asked about the share which they allocate to savings. The relative increase in savings from the constant to the changing scenario is at 9.46% largest for the group which claims to usually save between 10% and 25% of their income.

4 General equilibrium model

I now turn to a general equilibrium extension of the analytical model from section 2 and impose parametric assumptions. The core of my model follows closely the set up in the seminal paper by Krusell and Smith (1998), with life cycle extensions following Krueger et al. (2016). I extend this framework by introducing a non-stationary shift in the aggregate process, over which agents may have heterogeneous beliefs.

4.1. Households

There is a continuum of consumers of measure 1, a share Ω_{Wt} of young workers and the remaining share $\Omega_{Ot} = 1 - \Omega_{Wt}$ of old age and retired. The young workers face a probability $1 - \theta$ of retiring in the next period, while retirees die with a probability of $1 - \nu$. All deceased are replaced by young working consumers.

Agents can save a non-negative amount $a_{it} \geq 0$ in physical capital which is rented out to firms and pays a return r_t based on the aggregate state of the economy. A fraction δ of the capital stock depreciates during production, so that the net return equals $r_t - \delta$. All assets from the deceased are redistributed to surviving retirees proportionally to their current asset holdings[5].

Each worker is endowed with one unit of time and labor efficiency units $e_{it} \in \mathcal{E}$ from a finite set $\mathcal{E}$ which they supply inelastically to the labor market in exchange for the wage w_t. Efficiency units are stochastic and follow a Markov chain, where the probability of moving from state e to e' is given by $M^E(e', e)$. I impose $\int e_{it} di = 1$ for all t, so that labor supply is exogenously fixed at $L_t = \Omega_{Wt}$. Workers pay social security contributions as a fraction τ^{SS} of their labor income. The budget constraint of each working consumer is thus given by

$$c_{it} + a_{it+1} = (1 - \tau^{SS}) w_t e_{it} + (1 + r_t - \delta) a_{it}. \tag{4.1}$$

Retirees receive transfers b_t^{SS} from social security, so that their budget constraint is

$$c_{it} + a_{i,t+1} = b_t^{SS} + (1 + r_t - \delta) a_{it} / \nu. \tag{4.2}$$

Newly born workers are initially endowed with zero assets and randomly draw a skill level from the current distribution of efficiency units. Let ϕ denote the demographic characteristic of a consumer, i.e. age and skill level, with $\phi \in \Phi = \{O\} \cup \{(W, e) | e \in \mathcal{E}\}$. Now, define M as the transition matrix of the demographic process, so that $M(\phi', \phi)$ is the probability of moving from state ϕ to ϕ'. We denote the cash on hand for any individual in state (ϕ, a) by $\mathcal{B}(\phi, a)$ and their current income by $\mathcal{I}(\phi, a)$.

A consumer's per-period utility is given by a CRRA utility function $u(c) = \frac{c^{1-\sigma} - 1}{1 - \sigma}$ with parameter $\sigma > 1$[6]. The objective of an individual is to maximize their net present utility

$$\max_{c_{it}} \mathbb{E}_{i0} \left[\sum_t^\infty \beta^t u(c_{it}) \right]$$

subject to their respective budget constraint $c_{it} + a_{i,t+1} = \mathcal{B}(\phi_{it}, a_{it})$ and the borrowing restriction $a_{it+1} \geq 0$. I write $\mathbb{E}_{i0}$ to emphasize the dependence on current individual expectations.

[5]This can be interpreted as access to perfect annuity markets, see Krueger et al. (2016).

[6]As argued in Flynn et al. (2023), the homothetic specification guarantees an increase in savings following a perturbation of beliefs which decreases the continuation value of assets (see their footnote 10 which applies to my setting). Under more general preferences, the sign of the savings response depends on the relative elasticity of the marginal value of wealth.

4.2. Firm

There is a representative firm producing according to a Cobb-Douglas production function using capital and labor as inputs

$$\mathcal{Y}_t = F(K_t, L_t; \zeta_t) = \zeta_t K_t^\alpha L_t^{1-\alpha}.$$

Here, α denotes the capital share and ζ_t is a stochastic aggregate shock. The firm demands capital and labor until

$$r_t = F_K(K_t, L_t; \zeta_t), \;\; w_t = F_L(K_t, L_t; \zeta_t),$$

consistent with profit maximization.

4.3. Aggregate shock process and climate change

All aggregate shocks are transmitted via the multiplicative shock to productivity ζ_t. There are two states of the economy, a high state ζ^H and a low state $\zeta^L < \zeta^H$. The low state may represent a variety of disruptions to the global economic system or physical damages and has a positive likelihood even without climate change.

The values ζ_t are drawn independently over time with a per-period probability of the low state $p_t > 0$, which is allowed to vary over time. Specifically, I assume that there is a non-stationary variable T_t and a parameter γ so that

$$p_t = p(T_t) = p^{1-\gamma T_t}. \tag{4.3}$$

While path of the time-dependent variable T_t is assumed to be common knowledge, there may be disagreement about the parameter γ, determining the variation of p_t over time.

The variable T_t captures any relevant exogenous and deterministic aggregate trends over time. In the baseline model, only the increase in physical impacts from climate change matter. These are assumed to be fully identified by the current increase in global temperature, so that $T_t = \mathsf{T}_t$ is one-dimensional. However, climate change impacts on the economy may also include transitional effects, e.g. due to stranded assets in fossil fuel intensive sectors or innovations in carbon-neutral production. Different to the changes in the physical climate system, these impacts are unlikely to be permanent, and thus have to be accounted for separately. It is possible to extend the model by including a dummy variable which indicates whether or not productivity is currently harmed by transition, and then allow $T_t = (\mathsf{T}_t, \mathcal{T}_t)^{tr}$ to be a vector in $\mathbb{R}_{\geq 0} \times \{0, 1\}$. The parameter $\gamma = (\gamma_1, \gamma_2)$ becomes a row vector in $\mathbb{R}^2$, and the product in (4.3) is a scalar product. In both cases, rising temperature should never decrease the probability of the low state, so that $\gamma, \; \gamma_1 \geq 0$.

For current global temperature $Temp_t$, we set $\mathsf{T}_t = \min\{0, Temp_t - \overline{Temp}\}$ to be the increase over some threshold $\overline{Temp}$, beyond which temperature impacts on the aggregate economy become significant. This formulation is consistent with an interpretation of a *damage tipping point*, which is a temperature level above which climate damages become relevant, see also

Lontzek et al. (2024). From $t = 0$ onwards, the increase is governed by an AR(1) process

$$\mathsf{T}_{t+1} = \mu_T + \nu(\mathsf{T}_t - \mu_T) \tag{4.4}$$

where $\mu_T > 0$ is the long run temperature increase and ν is a persistence parameter. Requiring $p_t < 1$ for all t pins down the parametric restriction $\gamma\mu_T < 1$ and $\gamma_1\mu_T + \max\{0, \gamma_2\} < 1$, respectively.

The formulation here is slightly different to most integrated assessment models which assume deterministic changes to the level of productivity caused by climate change. Note that there is an implicit level effect, as a rise in p decreases the mean level of output. The stochastic formulation is a key feature of my model, as the uncertainty allows for disagreement over the aggregate process that is not immediately resolved when temperature increases. To ensure consistency, it is crucial to assume that all realized processes are possible under all distinct beliefs held within the population.

4.4. Consumer beliefs

Consumers are assumed to have perfect knowledge over the transition probabilities of demographics, i.e. the matrix M. Furthermore, the current aggregate states ζ_t and K_t as well as the deterministic process $\{T_s\}$ are known.

4.4.1. Beliefs over the aggregate shock

The parameter γ, while constant, is not observable by consumers. They only know that there are two possible values $\gamma \in \{0, \overline{\gamma}\}$. If T_t is two-dimensional, this implies they believe that either both physical and transitional effects matter for productivity, or that there is no time variation in p_t. For a given period t, let $\overline{\pi}_{it}$ denote consumer i's prior belief that $\gamma = \overline{\gamma}$, i.e. $\overline{\pi}_{it} = \mathbb{P}_{it}(\gamma = \overline{\gamma})$. In every period, everyone observes the state ζ_t and may update their beliefs to obtain a posterior belief π_{it}. Note that the current prior is given by the posterior of the previous period $\overline{\pi}_{it} = \pi_{it-1}$. Updating occurs following Bayes' rule. For a given prior $\overline{\pi}$ and a current level of the variable T, let $\tilde{\pi}(\zeta, \overline{\pi}, T)$ denote the updated belief after ζ is observed and $F(\zeta|\pi, T)$ denote the subjective distribution of ζ. For periods $t \leq 0$, there is no informational value in the aggregate state, so that beliefs are perfectly persistent.

In the baseline version and the calibration I assume that $\gamma = \overline{\gamma}$ is the correct state of the world. It is straightforward to allow for other cases, including those in which γ is actually stochastic, so that $0 < \pi < 1$ is the correct belief. In these cases, different to those of $\gamma \in \{0, \overline{\gamma}\}$, the correct belief is however not an absorbing state, as any realizations of ζ will lead to a consistent dynamic variance in beliefs.

4.4.2. Beliefs over aggregate capital

To solve their intertemporal decision problem, households need to form expectations over future wages and returns which depend on the endogenously determined aggregate capital stock. To accurately forecast prices consistent with rational expectations, they would have to keep track of the entire cross-sectional distribution, leading to an infinitely dimensional state variable. As in the original Krusell and Smith (1998) model, I instead assume that households are boundedly rational and use a *perceived law of motion* (PLM) $\mathcal{H}$ to forecast next period's capital. Their forecast will always depend on the current aggregate shock, the time-trend and capital. It may also depend on their personal belief π, change over time or include stochasticity. I discuss the specifications explicitly in section 4.8 and write for now

$$K' \sim \mathcal{H}(K, \zeta, T; \mathcal{X})$$

where $\mathcal{X}$ summarizes any additional dependencies and $\sim$ should be read as $=$ in the case of no stochasticity.

4.5. Recursive formulation of the consumer problem

The idiosyncratic state consists of the demographic state ϕ, individual assets a and the current belief π. Let Ψ denote the distribution over these individual states, which is defined over the space $\mathbb{S} = \Phi \times \mathbb{R}_{\geq 0} \times [0,1]$. Assume that the distribution over Φ is in its stationary equilibrium, so that the labor force does not vary over time. As agents only use the mean of the asset distribution, i.e. aggregate capital, to forecast future prices, their problem can be formulated as depending on the aggregate states capital K, ζ and trend variable T. The subscript captures a possible dependence on additional variables $\mathcal{X}$.

$$V_{\mathcal{X}}(\phi, a, \pi, K, \zeta, T) = \max_{c, a'} u(c) + \beta \mathbb{E}\left(V_{\mathcal{X}'}(\phi', a', \pi', K', \zeta', T')\right) \tag{4.5}$$

$$\begin{aligned} s.t.\ \ & c + a' = \mathcal{B}(\phi, a, K, \zeta) \qquad (4.6) \\ & \phi' \sim M(\cdot, \phi),\ \zeta' \sim F(\cdot|\pi, T) \\ & \pi' = \tilde{\pi}(\zeta', \pi),\ T' = \mu_T + \nu(T - \mu_T) \\ & K' \sim \mathcal{H}(K, \zeta, T; \mathcal{X}),\ \mathcal{X}' = \mathcal{G}(\mathcal{X}) \end{aligned}$$

This pins down the choice function $a'_{\mathcal{X}} = a'_{\mathcal{X}}(\phi, a, \pi, K, \zeta, T)$. The expectation is taken over future individual and aggregate states, ϕ' and ζ'.

4.6. Equilibrium

I define the equilibrium of this economy in two steps. In each period, the economy is assumed to be in *temporary equilibrium*. This concept is commonly used in settings of bounded rationality in dynamic problems, see for example Farhi and Werning (2019) and Moll (2024). Beliefs over the future are taken as given, so that a Nash equilibrium is attained when all consumers optimize according to their current expectations. In the *dynamic equilibrium*, the economy is assumed to be in temporary equilibrium within a period, but the realized process may differ from agents' perceptions.

Definition 1 In a period t, taking as given a PLM $\mathcal{H}(K, \zeta, T; \mathcal{X})$ and current state variables ζ_t, Ψ_t and T_t, a *temporary equilibrium* is defined as wage w_t, interest rate r_t and a choice function of households $a' = a'(\phi, a, \pi, K, \zeta, T)$ so that:

(a) The choice function solves the individual household problem defined in (4.5), taking prices as given.

(b) The representative firm sets $r_t = F_K(K_t, L_t; \zeta_t), \;\; w_t = F_L(K_t, L_t; \zeta_t)$, consistent with profit maximization.

(c) Capital and labor supply are given by the distribution Ψ_t:

$$L_t = \Omega_{Wt} = \int_{\{\phi=(W,\cdot)\}\times\mathbb{R}_{\geq 0}\times[0,1]} d\Psi_t, \qquad K_t = \int_{\Phi\times\{a\geq 0\}\times[0,1]} a d\Psi_t.$$

The markets for capital, labor and social benefits clear. $\diamond$

Definition 2 For given processes $\{\{\zeta_t\}, \{T_t\}\}_{t\geq 0}$, PLM $\mathcal{H}(K, \zeta, T; \mathcal{X})$ and initial histogram Ψ_0, the *dynamic equilibrium* of the economy is given by a sequence $\{\Psi_t\}_{t\geq 0}$ so that:

(a) Each period, the economy is in temporary equilibrium.

(b) The distribution evolves consistently with the exogenous law of motion for demographics, Bayes' formula, and the endogenous choice function a':

$$\Psi_t(\phi', a', \pi') = \int_{a'(\phi,a,\pi,K_t,\zeta_t,T_t)=a'} \int_{\phi} \int_{\tilde{\pi}(\zeta_t,\pi)=\pi'} \Psi_{t-1}(\phi, a, \pi) M(\phi', \phi)$$

$\diamond$

Note that the initial perceived law of motion $\mathcal{H}$ is not assumed to be an equilibrium outcome, which constitutes a crucial deviation from rational expectations. The algorithm to find a baseline choice of $\mathcal{H}$ discussed in 4.8 is specifically designed to closely approximate the realized process, and performs well at that goal as shown in appendix B.1.

A dynamic equilibrium exists under the standard assumptions posited above, see Miao (2006) and Cao (2020)[7].

4.6.1. Characterizing the equilibrium

As demographics evolve exogenously, the distribution over Φ will converge to its unique stationary equilibrium in all dynamic equilibria. We impose this distribution for all simulations. The stationary share of workers and retirees is given by

$$\Omega_W = \frac{1-\nu}{(1-\nu)+(1-\theta)}, \qquad \Omega_O = \frac{1-\theta}{(1-\nu)+(1-\theta)}.$$

Let Ω^E denote the stationary distribution implied by M^E.

In this case, labor is constant over time at $L_t = \Omega_W$. Both wages and interest rates are thus pinned down fully by capital and the aggregate shock ζ_t and given by

$$r_t = r(K_t, \zeta_t) = \alpha\zeta_t(\Omega_W/K_t)^{1-\alpha}, \qquad w_t = w(K_t, \zeta_t) = (1-\alpha)\zeta_t(K_t/\Omega_W)^{\alpha}. \tag{4.7}$$

[7]The setting considered in Miao (2006) allows for a non-stationary aggregate process. While Cao (2020) does not explicitly formulate a non-stationary problem, the updated proof on the existence of dynamic sequential competitive equilibria can easily be modified to accommodate non-stationarity. Note that in both papers, stationarity is necessary to consider recursive equilibria.

Furthermore, social benefits depend only current wages and are given by

$$b_t^{SS} = \tau^{SS} w(K_t, \zeta_t)\Omega_W/\Omega_R.$$

The first order condition of consumers with respect to the asset choice, the Euler equation, is given by

$$u'(c_{it}) \geq \beta\mathbb{E}[(1 + r_{t+1} - \delta)u'(c_{it+1})], \quad = \text{ if } a_{it+1} > 0.$$

Finally, the law of motion for beliefs is given by

$$\pi_{it} = \pi_{it-1}\mathcal{P}_{it}, \text{ where } \mathcal{P}_{it}^{-1} = \begin{cases} \pi_{it-1} + (1 - \pi_{it-1})p^{\overline{\gamma}T_t} & \text{if } \zeta_t = \zeta^L \\ \pi_{it-1} + (1 - \pi_{it-1})\frac{1-p}{1-p^{1-\overline{\gamma}T_t}} & \text{if } \zeta_t = \zeta^H. \end{cases} \tag{4.8}$$

The belief π increases in periods of the low state ζ^L and decreases for ζ^H.

In the case of $\zeta_t = \zeta^L$, the posterior π_{it} from a prior $\overline{\pi}_{it} = \pi_{it-1}$ is given by

$$\pi_{it}|(\zeta_t = \zeta^L) = \frac{p^{1-\overline{\gamma}T_t}\pi_{it-1}}{\pi_{it-1}p^{1-\overline{\gamma}T_t} + (1 - \pi_{it-1})p} = \frac{\pi_{it-1}}{\pi_{it-1} + (1 - \pi_{it-1})p^{\overline{\gamma}T_t}} > \pi_{it-1}.$$

In the case of $\zeta_t = \zeta^H$, updating is given by

$$\begin{aligned} \pi_{it}|(\zeta_t = \zeta^H) &= \frac{(1 - p^{1-\overline{\gamma}T_t})\pi_{it-1}}{\pi_{it-1}(1 - p^{1-\overline{\gamma}T_t}) + (1 - \pi_{it-1})(1 - p)} \\ &= \frac{\pi_{it}}{\pi_{it} + (1 - \pi_{it})(1 - p)/(1 - p^{1-\overline{\gamma}T_t})} < \pi_{it}. \end{aligned}$$

4.6.2. Understanding and interpreting dynamic equilibria

Every dynamic equilibrium of course depends crucially on the specific draw $\{\zeta_t\}$. Due to the non-stationary nature of the system, there is no natural point in time which lends itself as a basic point of analysis, usually taken to be a steady state. Interpretations of the model importantly cannot be based on time averages, which vary, but rather have to be based on ensemble averages.

I obtain interpretable results in section 5 by considering the output from many (usually 10000) simulations and averages or other statistics thereof. To ensure a good representation of the implied spread with a limited number simulations, I use a stratified sample as discussed in appendix B.1.

An alternative would be the consideration of a type of dynamic stochastic steady state, building on the concept of Coeurdacier et al. (2011). It is possible to formulate and compute the deterministic path resulting from model implied system equations and the exogenous average over shock realization. Theoretically this outcome may be far away from the simulated mean, but numerical simulations show no large deviations.

4.7. Calibration

Each time period is one year.

Life-cycle parameters The logarithm of efficiency units follows an AR(1) process

$$\log(e_{i,t+1}) = \rho \log(e_{i,t}) + \varepsilon_t$$

where $\varepsilon_t \sim \mathcal{N}(0, \sigma_\varepsilon^2)$. I estimate this process with GMM using time fixed effects and winsorized income data at the 1st and 99th percentile on reported net labor earnings from the subset of employed, working age individuals from all 14 available waves of the UK Understanding Society survey. This yields a persistence parameter $\rho = 0.93$ and a standard deviation of $\sigma_\varepsilon^2 = 0.073$. These estimates, especially the variance, are rather higher than comparable studies. As responses from a general survey are expected to be more noisy than those in specific income dynamics studies, I assume for my baseline $\rho = 0.9$ and $\sigma_\varepsilon^2 = 0.03$. The standard deviation of the skill process can be derived by $\sigma_e^2 = \sigma_\varepsilon^2/(1-\rho^2) = 0.157$.

The expected duration of working life and retirement is assumed to be 40 and 20 years, respectively, implying $1-\theta = 1/40$ and $1-\nu = 1/20$. I assume a replacement rate during retirement of 60%, leading to a social security tax of approximately $\tau_{SS} = 23.08\%$. These slightly higher estimates compared to Krueger et al. (2016) reflect recent demographic changes.

Aggregate shock and temperature process I assume $\zeta^H = 1$ and $\zeta^L = 0.93$ so that the economy produces 7% less output in the bad state. The probability p of a low state for $T_t = 0$ is 15%, so that currently, average output loss is equal to 1.5%, consistent with the estimates in Rising et al. (2022) for 2022. Long run temperature is assumed to be $0.9°C$ above current levels, so that $\mu_T = 0.9$. Most of this transistion is projected to happen by the end of this century, which I match with $\nu = 0.9$, corresponding to $T_{75} = 0.895$. The parameter $\overline{\gamma} = 0.7$ is chosen so that in the long-run, the probability approaches 0.5, corresponding to an average output loss of 3.5%, which Rising et al. (2022) estimate as the effect in 2050. The global temperature increase should here be interpreted as a sufficient statistic measuring the extent of climate change. In particular, the stylized framework may capture a wide range of impacts, for example flooding, agricultural losses and heatwaves, but also disruptions of the global economy.

Preferences and production Utility is given by a CRRA function with a risk aversion of $\sigma = 2$. The Cobb-Douglas parameter for production is set to $\alpha = 0.33$ and capital depreciates at a rate $\delta = 0.1$. The discount factor is assumed to be $\beta = 0.98$ to match a capital to output ratio of 2.71 in the Aiyagari version of the model without aggregate risk.

Grid choices and initial values The income process is discretized to a grid of $n_e = 7$ nodes using the Tauchen procedure, so that there are $n_\phi = 8$ distinct demographic states. I choose $n_T = 5$ nodes to model the temperature (4.4).

The asset grid is chosen to be large and denser towards the borrowing constraint by using a root spaced grid. I set $a_{\max} = 40$ and $n_a = 200$. In stochastic steady state distribution without climate change, 50% of the total mass of consumers is concentrated at the lower 35 nodes, and 98% within the lower 100 nodes.

The baseline level of capital K_0, around which the grid is spanned, is chosen to be the market clearing level of an Aiyagari version of the model without aggregate risk. The shock ζ is then constant at its expected mean given $\gamma = 0$, i.e. $\overline{\zeta} = 0.985$. In this version, aggregate variables do not change over time and are known to all agents. I span an equidistant grid of $n_K = 25$ gridpoints on $[0.8K_0,\ 1.2K_0]$.

Finally, I pick $n_\pi = 5$ equidistant nodes to discretize the belief state on $[0, 1]$. It is important to include the two boundary points $pi = 0, 1$ in the grid to allow for long run convergence.

Overall, the grid captures $n_\phi \cdot n_a \cdot n_\pi = 8000$ distinct idiosyncratic states and $n_K \cdot n_T \cdot n_\zeta = 250$ distinct aggregate states, leading to an overall state space of 2 million nodes to be considered in the individual choice function.

4.8. Computational method

This section discusses the algorithm used to find $\mathcal{H}$, as well as alternative approaches used for comparison and robustness. The methods used for solving the consumer problem and the dynamic equilibrium are more standard and can be found in appendix B.3.3.

4.8.1. Baseline PLM

In my baseline, $\mathcal{H}$ may depend on the idiosyncratic belief π as well as the aggregate states K, ζ and T. For an agent with belief $\pi \notin \{0,\ 1\}$, $\mathcal{H}$ is assumed to be a weighted average of the PLMs for extreme beliefs

$$\mathcal{H}_\pi(K, \zeta, T) = (1 - \pi)\mathcal{H}_0(K, \zeta) + \pi\mathcal{H}_1(K, \zeta, T).$$

This leaves us with the task to find suitable approximation for the extreme cases, $\pi \in \{0, 1\}$. Here, I follow closely the original work by Krusell and Smith (1998) who show that a first order difference equation can well approximate the law of motion of capital for a given aggregate state[8]. In the non-stationary setting, I assume a similar fixed functional form

$$\log(K^+) = a_T^\pi + b_T^\pi \cdot \mathbb{1}_{\zeta = \zeta^L} + (c_T^\pi + d_T^\pi \cdot \mathbb{1}_{\zeta = \zeta^L}) \log(K) \tag{4.9}$$

in which the parameters $(a_T^1, b_T^1, c_T^1, d_T^1)$ are quadratic polynomials in T. As the productivity process is believed to be independent of T under beliefs $\pi = 0$, so is the PLM. The coefficients are found using a slightly modified version of the Krusell-Smith algorithm, in order to account for the non-stationarity. Fix some initial distribution Ψ_0. For $\pi \in \{0, 1\}$, do the following:

(1) Make an initial guess for the coefficients of $\mathcal{H}_\pi$.

(2) Solve the consumer problem.

(3) Draw an ensemble of n_{sim} sequences over T_{sim} periods of ζ from the distribution $F(\zeta|\pi, T)$ using the stratified sampling algorithm described below. Compute the corresponding ensemble of dynamic equilibria.

[8] Under the common assumption of CRRA utility, the implied consumption function is close to linear in assets except close to the borrowing constraint. As asset-poor agents contribute a negligible amount to overall capital, the asset choice approximately aggregates, so that the mean of capital performs well as sufficient statistic.

(4) Update the coefficients of $\mathcal{H}_\pi$ by regressing $\log(K_{t+1})$ on lagged aggregate variables. Iterate until coefficients converge.

The regressions on simulated data quickly and consistently satisfy both $R^2 > 1 - 10^{-4}$ and $MSE < 10^{-8}$. Due to low effect sizes and significance levels on all interaction terms including both the productivity shock indicator and temperature, I drop those terms in the baseline specification, which leads to 8 unknown parameters in $\mathcal{H}_1$. It takes about 45 minutes on a MacBook (M1 chip, 2020, RAM 16GB) to find the 12 coefficients for both PLMs with $n_{sim} = 1000$ and $T_{sim} = 200$ under the error bound 10^{-5}.

The ensemble draw in step (3) is necessary due to the non-stationarity. While the choice for n_{sim} and T_{sim} yield a large number of observations overall, random draws may lead to large deviations of the ζ^L share across the number of draws from p_t within a time period. To ensure matching the share correctly, I use stratified samples within each period. This substantially decreases the variation across periods, while still accurately matching the spread in outcomes within a period.

Due to time-dependence, the resulting PLM will always depend on the initial distribution Ψ_0[9], making its specification a crucial implementation choice. For the simulation algorithm, I choose the stationary distribution from the Aiyagari model and assume that all agents share the belief π starting from $t = 0$. With the converged coefficients in hand, I compute the implied stochastic steady state distribution, which I use to initialize an additional ensemble. The good fit of the converged PLM on simulated capital paths serves as validation.

Note that the simulation algorithm does not have to account for learning, as it is only used for the extreme cases $\pi \in \{0, 1\}$. Agents are further assumed to be unaware of anyone with different beliefs in the economy when forecasting capital. For inner values of $\pi \in (0, 1)$, however, agents can be interpreted as only assuming that their personal belief is the mean of the population, but being open to other beliefs in the economy. I show in appendix B.1 that the resulting forecasting rule does well in approximating the path of capital under accurate beliefs for all priors.

Appendix B.1 provides details on model selection, sampling procedure and forecast performance.

4.8.2. Accounting for future learning

The future state ζ' does not have a direct effect on the law of motion, as capital accumulation is determined by current savings. However, the future state affects the belief π, so that there will be an indirect learning effect. An alternative specification $K' \sim \mathcal{H}_{\pi'}(K, \zeta, T)$ makes future capital stochastic as it depends on the future belief π', which is affected by next period's aggregate state ζ'. The quantitative implications of this additional channel are small.

4.8.3. Adaptive PLM

The formulation above abstracts from any distributional effect on capital accumulation. As beliefs affect savings choices, the cross-sectional beliefs of the population matter for aggregate

[9] In a stationary model, implementations of the Krusell-Smith algorithm often exclude the first few thousand simulation steps to ensure independence of initial values.

savings. Particularly in the non-stationary framework, more concerned agents grow richer over time, which pushes up their marginal propensity to save further. Thus, we might expect a persistent error between predicted and realized capital. In the static approach above, agents do not improve on $\mathcal{H}$ if their predictions about future capital were wrong before.

In an alternative specification, I allow for an adaptive PLM, meaning that households update the function $\mathcal{H}$ after observing outcomes from previous periods. This extension adresses the critique brought forward by Moll (2024): Instead of assuming that agents simulate the economy forward, they base their beliefs on observed variables. This point becomes more critical in a non-stationary framework, where we cannot interpret the simulation as an extrapolation from previous observations.

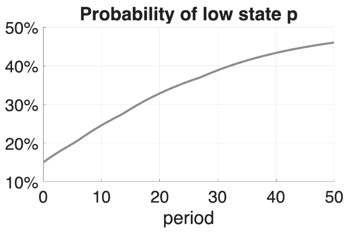
Static expectations A particularly simple way to incorporate adaptive beliefs over capital accumulation into this framework is to assume naive expectations, under which agents believe that capital next period will be the same as today, so that $\mathcal{H}^{stat}(K) = id_K$. As capital actually varies dynamically, even before the non-stationary shift, this is a substantial deviation from rational expectations. The behavior of agents under these static expectations coincides with the set-up in the analytical model of section 2. Note however that the globally solved consumption function accounts for higher order effects not present in the linear response of Proposition 1.

The implementation of a dynamic with a static PLM is straightforward and particularly fast, as it is only necessary to solve once for the choice function over the aggregate grid.

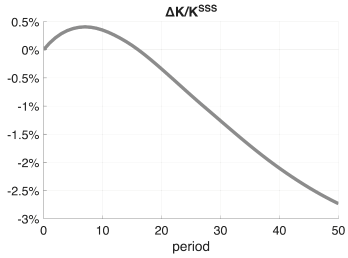
Updated forecasting rule A more sophisticated approach to allow for adaptive expectations is the assumption of a forecasting rule with a fixed functional form and dynamic updating of its parameters. Such an approach becomes substantially more computationally intensive, as the choice function has to be solved for after each parameter update. The alternative approach of including PLM parameters as aggregate state variables increases the computational burden even more due to the curse of dimensionality.

I develop an algorithm for an adaptive forecasting rule in appendix B.2. In this version of the model, all agents are initially unaware of the general equilibrium effects of the temperature shift on capital and jointly update their law of motion periodically after a fixed time horizon. In particular, there is no disagreement over capital accumulation.

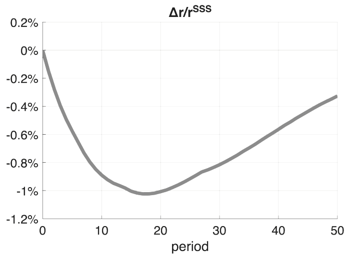
A key question the modeler faces in the non-stationary setting is whether or not to let the agents account for the non-stationary shift in capital. To tease out the implications of this channel without introducing an additional learning parameter, I assume a constant degree of memory over the law of motion. An ad-hoc way of incorporating memory dependence is simply to use a convex combination between an updated and previous guess. The extreme case of ever-lasting memory can be implemented by carrying and updating the covariance matrix of the regression separately.



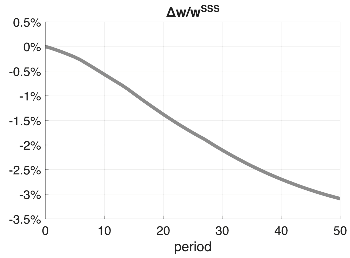
(a) Probability of low state



(b) Aggregate Capital



(c) Rate of return



(d) Average wage

Figure 1: Dynamics of the probability p_t of the low state and of key aggregate variables under accurate beliefs. Panels (b)-(c) show deviations from the stochastic steady state value, averaged over 1000 simulations.

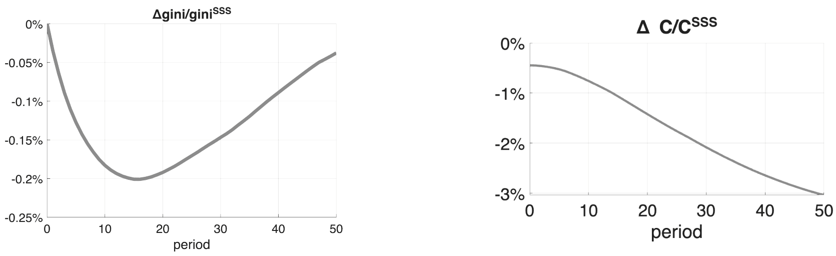
5 Macroeconomic effects of climate beliefs

5.1. Macroeconomic dynamics under climate change

5.1.1. Accurate homogeneous beliefs

To illustrate the dynamics caused by the shift in temperature, we first focus on the case of homogenous and accurate beliefs. In period 0, everyone becomes aware of the increase in temperature and its effect on the likelihood of the low probability state. Figure 1 shows the time series of the probability p_t as well as the averages across 10000 draws of the dynamic equilibrium of key aggregate variables. The simulation of an ensemble with 10000 draws takes about 3 minutes. Initially, the higher incentive to save caused by changed beliefs leads to a slight increase in capital, but after about 10 periods, the physical effect of the changed aggregate process dominates and average capital decreases to its new long run average. The rate of return drops initially, due to both the decreased average productivity and the increase in capital. As the capital stock diminishes, the rate of return picks up again. Average wages decrease as climate change progresses, with an initially muted effect due to the rise in capital.

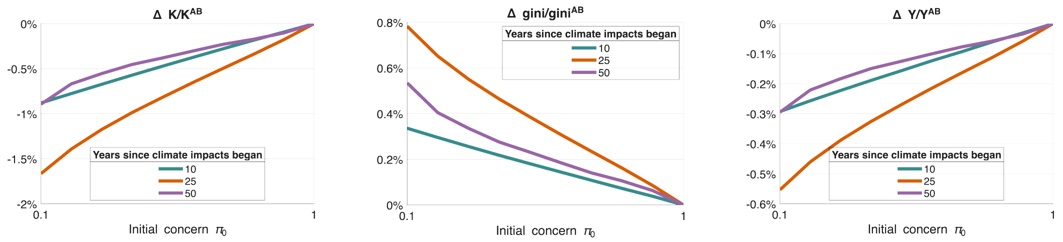
Figure 2 illustrates the distributional consequences of the shift in temperature. As capital rises and the rate of return falls, wealth inequality as measured by the Gini coefficient slightly drops. In the long run, however, the reduction in productivity increases wealth inequality. Consumption within the first quintile of the wealth distribution is depicted as the dashed line in panel 2b. As this group includes the share of non-savers who do not react to the increase in p_t, consumption of this group initially decreases less than the average. The relative decrease in the long run however is lower.



(a) Gini coefficient

(b) Consumption

Figure 2: Distributional dynamics. The figures show deviations from the stochastic steady state value, averaged over 10000 simulations. In panel (b), the solid line is average consumption, the dashed line is average consumption within the first wealth quintile, and the dotted line is average consumption within the fifth wealth quintile.



(a) Capital

(b) Gini

(c) Output

Figure 3: The figures show deviations between average outcomes under inaccurate compared to accurate beliefs.

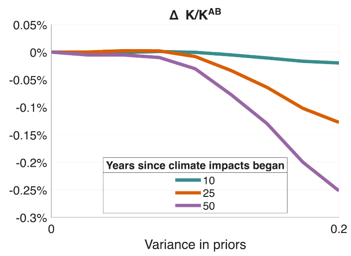
5.1.2. Inaccurate homogeneous priors

To assess the relationship between overall concern over climate change in the economy, I first vary the homogenous belief over π while still assuming no variance.

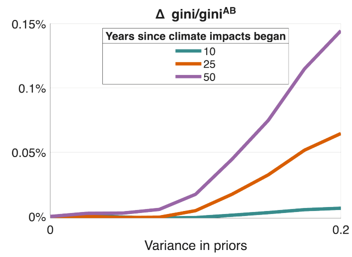
Figure 3 shows the deviations for average capital trajectories at different points in time, relative to the outcomes of a dynamic equilibrium with accurate beliefs. We first note that a low prior leads to a consistently lower levels of capital. Over time, as capital is a state variable, the difference between capital holdings of a concerned and unconcerned economy increases, seen from the increasing slope of the curves for years 10 and 25. In the long run, however, the learning mechanism leads to a convergence of beliefs which is transmitted to a convergence in capital - consequently, the difference becomes much smaller by period 50. The effect on capital passes through to differences in output. In net present value terms, climate change leads to 12% higher output losses in the case of low concern than in the case of accurate beliefs.

The impact of beliefs on the macroeconomy also have distributional effects, as evident from the movement in the gini coefficient. Lower aggregate capital disproportionally affects those who rely on labor income, so that a low average belief over climate change increases wealth inequality. This effect is also slightly more persistent than the movement in capital; we still observe a 0.4% increase in the gini coefficient after 50 years.

This figures abstract from the case of ignorant beliefs. As complete certainty prohibits any type of learning, a belief of $\pi = 0$ leads to permanent deviations of savings choices, even as low productivity states become more frequent. Note that this is still rational: due to formulation of climate change as an effect on the distribution of the aggregate process, there



(a) Capital



(b) Gini

Figure 4: The figures show deviations between average outcomes under inaccurate compared to aggregate beliefs. The scale starts zero variance, and increases up to 0.2.

is a positive probability of low and high productivity states in each period for all values of π. Under a belief of $\pi = 0$, a realization that was actually drawn from the non-stationary productivity process is unlikely, but possible. However, note that there will be a consistent error in the capital forecast which is not assumed to be stochastic.

5.1.3. The role of disagreement

I repeat the previous analysis with a varying level of variance in priors to assess the relevance of diagreement for aggregate outcomes. The mean of π_0 is fixed at 0.7. In all cases other than $\text{Var}(\pi_0) = 0$, no agent has extreme beliefs $\in \{0, 1\}$; the belief distribution is fitted based on a Beta distribution as explained in appendix B.3.3[10].

First, we note that disagreement only decreases capital. In comparison to variations in the first moment, disagreement has small effects. Even for a high levels of disagreement, capital only deviates by up to 0.3% from the case of no disagreement within the first 50 years. Interestingly however, the effect of disagreement is more persistent than the one of average beliefs, and it still increases 25 years after climate impacts began. This is particularly of note as beliefs converge independently. In the case of disagreement, there are additional general equilibrium effects relative to the case of homogeneous, but inaccurate, beliefs, as the saving behavior of more concerned agents pushes down the interest rate and thus the incentive to save of the less concerned ones.

The increase in the gini coefficient is partly explained by the wage effects of the decrease in capital for rising variance, analogous to the consideration of average beliefs. Under disagreement however, there is an additional mechanical divergence between asset holdings of agents with differing beliefs, due to the different savings incentives under a variation in priors. It is however not obvious how quantitatively important this second channel is, or what other distributional effects are masked by the movement in this aggregate statistic. In particular, considerations of inequality in the case of disagreement need to account for not only variations in wealth and income, but also for heterogeneous outcomes for different initial beliefs.

[10]Note that the variance of a Beta distribution with mean μ is bounded by $\mu(1-\mu)$, i.e. 0.21 for $\mu_\pi = 0.7$.

5.2. Mechanisms

5.2.1. Individual savings choices in general equilibrium

This section explores in detail the individual savings choices within the general equilibrium model, which drive capital accumulation in the aggregate. While section 2 provides important insights into the effect of a marginal change in beliefs on savings choices by uncovering the first-order drivers of the response, it becomes necessary to consider computational results from the globally solved model in order to examine responses under large shifts, which are more realistic in the case of climate change.

I denote by savers all agents who save part of their current income and thus choose $a' > (1-\delta)a$. This is a more restrictive characterization of saving than choosing to be asset unconstraint in the next period, i.e. $a' > 0$, and includes only those agents who do not rely on their savings for current consumption.

Under the baseline PLM, the asset choice $a'(\phi, a, \pi, K, \zeta, T)$ varies in the cross-section for a given aggregate state due to heterogeneity in the demographic state ϕ, asset holdings a and the belief π. As discussed in section 2, the difference in asset choices between otherwise identical agents with different π depends on their current idiosyncratic state. Similarly, asset choices of course depend on the current aggregate state, as individuals smooth consumption in periods of low income, which depends both on the shock ζ and current capital K.

Table 7 illustrates the difference in savings choices between concerned and unconcerned agents in three key statistics: the likelihood to save and savings as a share of income, both on average and conditional on saving when unconcerned. To account for dependency on the aggregate state, I report these values for an individual moving from state $\pi = 0$ to $\pi = 1$[11] for the high and low productivity state, different levels of temperature and capital at its stochastic steady state value before and after the climate transition[12].

First, we notice that the increase in likelihood to save from being more concerned about climate change is higher for the low than the high productivity state as long as temperature is still low. All agents have an incentive to save in good times, so that they can use their savings in bad times in order to smooth consumption. Those who believe that the bad times only happen infrequently engage more in consumption smoothing and thus have a higher likelihood to stop saving in periods of low productivity. As temperatures increase, the high state only happens on average once every two years, and concerned agents become much more likely to be savers in all states of the world. Variation between productivity states however matters little for differences in the savings share.

As temperature increases, short-run impacts are larger, so that a shift in beliefs has higher effects across all of the key indicators. In particular, the likelihood to save shoots up substantially for $T = \mu$. The level of capital also matters more for the choice whether or not to save

[11]Comparing the edge cases of beliefs has the benefit that there is no learning effect of the current productivity state.

[12]Before the transition to high temperatures, aggregate capital falls below K_{CC}^{SSS} in about 12% of simulations, and similarly, after the transition, aggregate capital is above K_0^{SSS} in roughly 10% of simulations. In particular, the consumption function is well-defined for all combinations presented in table 7, and these values are present in the capital PLM estimation. For both levels of capital, the underlying asset distribution is taken to be the one of the respective SSS.

		$T=0$		$T=\mu/2$		$T=\mu$	
		K_0^{SSS}	K_{CC}^{SSS}	K_0^{SSS}	K_{CC}^{SSS}	K_0^{SSS}	K_{CC}^{SSS}
Likelihood to save	ζ^L	0.370%	0.179%	0.927%	0.535%	2.314%	3.374%
	ζ^H	0.260%	0.000%	0.481%	0.250%	14.303%	15.396%
Savings share	ζ^L	0.236%	0.233%	0.452%	0.466%	0.780%	0.819%
	ζ^H	0.255%	0.249%	0.513%	0.527%	0.978%	1.025%
Savings share conditional	ζ^L	0.390%	0.384%	0.746%	0.768%	1.288%	1.349%
	ζ^H	0.355%	0.347%	0.714%	0.732%	1.361%	1.425%

Table 7: Average differences between agents with $\pi = 1$ and those with $\pi = 0$ in their likelihood to save and their savings share (relative to current income). The savings share in the final row is taken conditional on the agents saving under $\pi = 0$.

rather than the savings share. Non-savers tend to be asset poor, so that their income is driven mostly by wages and decreases for a low level of capital. If they experience an unusually low level of capital at the beginning of the climate transition they will still expect capital to increase again, thus shifting consumption forward. Consequently, the response is higher for the high level of capital as long as temperature is still low. In the long-run, however, the low level of capital is the new normal and expected marginal value of savings are increased. In the unusual case of high capital under high temperatures, savings are higher anyway, so that the difference between beliefs matters less than for low capital.

Turning to cross sectional variation, I report below the same statistics separated for different groups: table 8 reports values for the different income levels, and 9 for the lowest, middle and highest wealth quintile. The aggregate state is fixed at $T = \mu/2$ and $K = K_0^{SSS}$, and I report the expected averages of responses in the high and low productivity state under the probability $p_{\overline{\gamma}}(\mu/2)$. I further report the baseline values of these statistics in the case of $\pi = 0$.

In the model, high income agents save in either case, so that their likelihood to save is unaffected by a change in beliefs. The entire extensive margin effect is thus due to low income and retired agents, as shown within the first line of 8. The average increase of the savings share within the group of low income agents when becoming more concerned is very small at less than 0.04% of income. This effect is however mostly driven by those who do not save at all, which makes up more than 90% of all low income agents. When restricting the sample to those who do save, the effect substantially increases to 0.46%, and actually becomes higher than within the group of high income agents, who only increase their savings share by 0.35%. We see similar changes for retirees, another group with a large share of non-savers: for those retirees who already save, the increase in concern prompts them to save 0.64% more of their income, even though the average retiree only increases their savings share by 0.2%.

Similarly as with income, whether or not and how much agents save depends crucially on their current wealth holdings. For those who are in the lowest quintile of the wealth distribution, the likelihood to save increases by 2.22% when they become more concerned over climate change, a number that drops to 1.07% within the middle wealth quintile and is

		Income			
		low	median	high	retired
Likelihood to save	difference	0.325%	0.000%	0.000%	0.814%
	$\pi = 0$	8.250%	100.000%	100.000%	31.221%
Savings share	difference	0.038%	0.486%	0.347%	0.198%
	$\pi = 0$	1.132%	24.898%	56.072%	4.530%
Savings share (cond)	difference	0.459%	0.486%	0.347%	0.635%
	$\pi = 0$	13.618%	24.898%	56.072%	14.437%

Table 8: Average differences between agents with $\pi = 1$ and those with $\pi = 0$ within income and wealth groups.

		Wealth		
		Q1	Q3	Q5
Likelihood to save	difference	2.218%	1.074%	0.000%
	$\pi = 0$	24.102%	82.839%	100.000%
Savings share	difference	0.172%	0.437%	0.402%
	$\pi = 0$	3.145%	16.888%	37.986%
Savings share (cond)	difference	0.733%	0.528%	0.402%
	$\pi = 0$	13.315%	20.321%	37.986%

Table 9: Average differences between agents with $\pi = 1$ and those with $\pi = 0$ within income and wealth groups.

zero for the richest group, in which everyone saves anyway. While the average effect on the savings share of the poorest quintile is again quite low at 0.17%, it is much more substantial within the group of savers at 0.73%.

Disentangling beliefs over climate shocks and capital accumulation As the PLM for capital depends on the current belief π, the variation above includes both the effect of differing expectations over productivity shocks and over future capital. To disentangle the effects, I also compute asset choices under two alternative laws of motion: first, everyone continues to assume the PLM from before the climate transition, and second, everyone has static expectations over capital, thus acting as if future capital will be the same as today. Table 10 reports the differences in likelihood to save and savings shares across these three different PLM, all at $T = \mu/2$ and K at its initial SSS value.

Both statistics show the largest effect of different beliefs over the aggregate process for the case of homogeneous forecasting rules for capital across the economy. As illustrated in appendix **??**, the non-stationary PLM predicts higher capital next period for all relevant aggregate states. Thus, if an agent becomes more concerned over future shocks without

		Baseline	Homogenous	Static
Likelihood to save	ζ^L	0.927%	2.258%	0.401%
	ζ^H	0.481%	0.743%	0.257%
Savings share	ζ^L	0.452%	0.913%	0.258%
	ζ^H	0.513%	1.017%	0.324%

Table 10: Average differences between agents with $\pi = 1$ and those with $\pi = 0$, at $T = \mu/2$ and $K = K_0^{SSS}$.

changing the forecast over capital, they expect overall output to be even lower in the future and thus save even more. Decreasing disagreement over capital dynamics in an economy with different expectations over climate impacts thus contributes to higher heterogeneity in choices.

On the other hand, an agent who expects capital to stay constant reacts the least to a shift in beliefs over aggregate shocks. The static forecast suppresses the effects of more frequent low productivity shocks to the capital stock, so that the decline in future output is underestimated. However, quantitatively, the effect of static expectations on the savings statistics is small. Note the slight distinction to section 2, even though the underlying capital forecast is identical: the globally solved individual choice function accounts not only for higher order effects, but also for the large-scale shifts expected under climate change.

5.2.2. The relevance of heterogeneity for aggregate effects

The explicit model of heterogeneous agents not only reflects the direct incorporation of micro evidence in a general equilibrium framework, but also allows the consideration of distributional effects such as movements in the gini coefficient. A natural question however is whether or not the aggregate results would also be generated in a representative agent economy, a model of which is much simpler and can be solved without a capital forecast rule. A representative agent with standard CRRA utility also prefers to save more when concerned about climate change, driven by precautionary motives and an IES below unity. In contrast to agents in a heterogeneous agent economy, however, they are not concerned about becoming borrowing constrained. The idiosyncratic uncertainty enters the consumption response in proposition 1 via the expected benefit of marginal savings captured in $\mathcal{D}$, but the extent to which this drives aggregate capital accumulation is not obvious.

To explore the quantitative relevance of uninsurable idiosyncratic risk, I implement a simple modification of my model in which the continuum of households is replaced by a social planner who wishes to maximize expected aggregate utility. This setting coincides with the one of a representative agent, as there are no market inefficiencies. The planner choice of consumption as a function of today's productivity shock, capital and temperature can be easily computed by value function iteration.

Concern about climate change pushes up savings, but it does so much less than in the full model. Figure 5 compares the simulation average timepaths of capital between the social

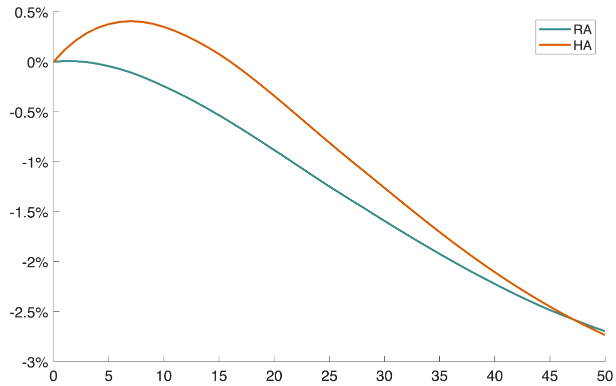
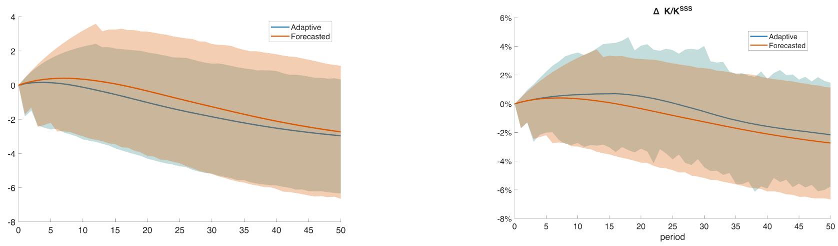


Figure 5: Capital over time, relative to respective initial stochastic steady stata



(a) Fully adaptive beliefs

(b) Adaptive beliefs with infinite memory

planner and the heterogeneous agent economy, both relative to their initial stochastic steady state and under accurate beliefs. This comparison shows the critical role of heterogeneity at the micro level and incomplete markets to generate a short-run increase in capital holdings.

5.2.3. Expectations over capital

Section 5.2.1 shows that the PLM matters for savings choices on the micro level. In this section, I examine how relevant expectations over the capital process are for aggregate outcomes.

Figure 6a compares the trajectories of capital under the temperature dependent forecast rule and under fully adaptive expectations, in which capital is simply assumed to stay equal to its current value. Aggregate capital rises less when the capital feedback is suppressed, consistent with the comparative statics reported in table 10.

6 Conclusion

This paper examines an increase in individual savings as a response to concern about climate change. Motivated by the predictions of a theoretical consumption-savings model, I first present empirical evidence on higher savings of individuals who are more concerned about climate change. A general equilibrium model shows how accurate beliefs increase output and thus welfare indirectly through their effect on savings as the economy moves along the climate transition path. These mechanisms uncover a dual role of savings in times of transition. For an individual, savings serve as an insurance against low states, to ensure consumption smoothing, and the incentives to do so increase under climate change. On the aggregate level, a rise in capital increases output and thus partly offsets the damages from climate change. Importantly, this effect is purely due the social value of savings, and does not affect individual incentives.

Importantly, the impacts of a rise in capital are not evenly distributed along the wealth distribution: Poor households are the ones who suffer most from inaccurate average beliefs, as wages decrease due to undersaving. This mechanism increases wealth inequality. Both the aggregate and distributional results emphasize the social value of savings, complementary to the private value which determines the individual responses. In particular, if a policy maker is more aware of an aggregate shift than the public, they may choose to incentivize savings exogenously to mitigate utility losses along the transition path.

While this paper focuses climate change, the general model and its solution method can be applied to a broad range of questions surrounding non-stationary, aggregate shifts in heterogeneous agent models, including the rise of artifical intelligence or the fertility decline.

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A Analytical model

A.1. Analytical derivations

Proof (Proposition 1) We drop the index i in this appendix. Combining the Euler equation and the envelope theorem yields

$$u'(c_t) = \beta \mathbb{E}[V'(a_{t+1})].$$

A perturbation of the system by dp_s for any $s > t$ can be written as

$$\begin{aligned} u''(c_t)dc_t = \beta \Big\{ &\left(\mathbb{E}[V'(a_{t+1})|\zeta^L] - \mathbb{E}[V'(a_{t+1})|\zeta^H] \right) dp_{t+1} \\ &+ \mathbb{E}[V'']da_{t+1} + \mathbb{E}\left[dV'|_{da_{t+1}=0} \right] \Big\}. \end{aligned} \tag{A.1}$$

We write

$$\mathcal{D}_t = \frac{\mathbb{E}[V'(a_{t+1})|\zeta^L] - \mathbb{E}[V'(a_{t+1})|\zeta^H]}{\mathbb{E}[V'(a_{t+1})]}$$

for the expected difference in marginal value between the low and high aggregate state, relative to the overall expected marginal value. As there is no income effect, $da_{t+1} = -dc_t$ holds. Exploiting the identity $MPCu''(c) = \beta MPS\mathbb{E}[V'']$ and using the elasticity of intertemporal substitution ε for convenience of notation leads to

$$\frac{dc_t}{c_t} = MPS_t\varepsilon_t \left\{ \mathcal{D}_t dp_{t+1} + \frac{\mathbb{E}[dV'|_{da_{t+1}=0}]}{\mathbb{E}[V']} \right\}.$$

The final term $\mathbb{E}[dV'|_{da_{t+1}=0}]$ may be different from zero only due to substitution in the future, caused by $dp_s > 0$ for $s > t+1$. An application of the envelope theorem shows

$$dV'|_{da_{t+1}=0} = R_{t+1}u''(c_{t+1})dc^S_{t+1}$$

where dc^S is the Slutsky compensated demand change. But this is precisely the response just derived for dc_t, which can be plugged in to obtain

$$R_{t+1}u''(c_{t+1})dc^S_{t+1} = R_{t+1}\frac{u'(c_{t+1})}{\varepsilon_{t+1}}\frac{dc^S_{t+1}}{dc_{t+1}} = V'_{t+1}MPS_{t+1}\left\{ \mathcal{D}_{t+1}dp_{t+2} + \frac{\mathbb{E}\left[dV'_{t+2}\right]}{\mathbb{E}[V'_{t+2}]} \right\}.$$

Solving the system forward gives the time 0 response in terms of fundamentals

$$\frac{dc_0}{c_0} = MPS_0\varepsilon_0 \sum_{t=0}^{\infty} \left(\sum_{\theta^t} \mathbb{P}^*(\theta^t) \left(\prod_{j=1}^{t} MPS(\theta^j) \right) \mathcal{D}_t(\theta^t) \right) dp_{t+1} \tag{A.2}$$

where

$$\mathbb{P}^*(\theta^t|\theta^{t-1}) = \mathbb{P}(\theta^t|\theta^{t-1})\frac{V'(a_t,\theta^t)}{\mathbb{E}[V'(a_t,\theta^t)]}$$

is the risk-adjusted weight on the state θ^t. □

To first order, the positive effect on asset holdings does not affect the marginal propensity

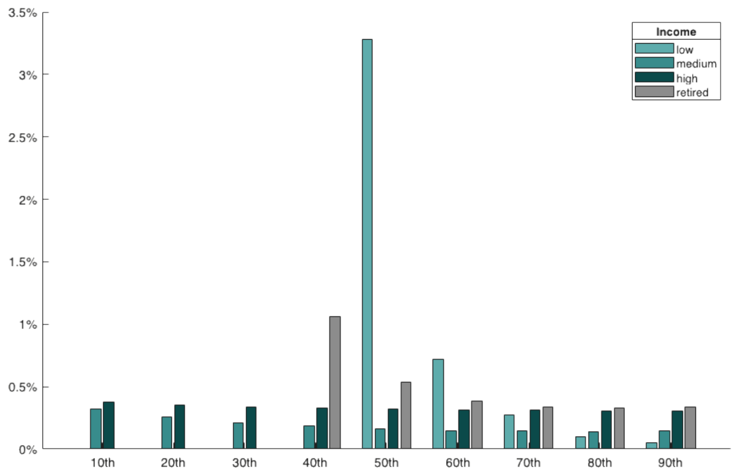


Figure 7: Relative response $-d \ln c_0 / dp_1$, grouped at asset percentiles within earnings states. The teal bars are workers, with darker shades representing higher current earnings, and the gray bars are retirees.

to save. As a consequence, the response to dp_{t+1} does not depend on dp_t.

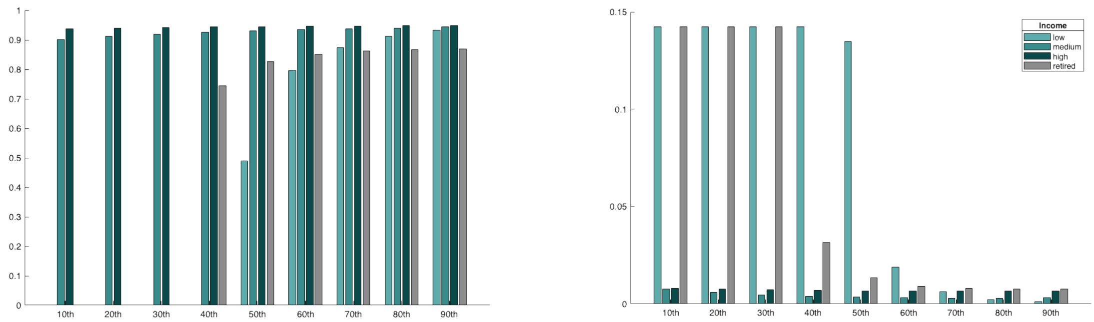
A.2. Numerical illustration

To illustrate the insights from the analytical model, this section shows partial equilibrium responses to a shift in dp_t using the calibration of the general equilibrium model discussed in section 4. Households are either working or retired, with a fixed probability of retiring and dying. Workers have an idiosyncratic earnings state, which follows an AR(1) process. I further assume the asset distribution of the stochastic steady state. In particular, asset holdings are correlated with income.

Figure 7 shows the consumption responses to dp_1 differentiated at income levels and the wealth percentiles of the respective idiosyncratic group. The relevant factors determining the consumption response, MPS and $\mathcal{D}$, are depicted in figure 8. For low earning households with low asset holdings, the change in probability has no effect: These agents consume their entire income and do not make intertemporal decisions, so that they have a zero MPS. As wealth increases, so does the MPS[13], and the increased expected marginal value of holding assets in the low versus the high state $\mathcal{D}$ becomes the relevant driver of the response. This is highest for those who are currently poor. Retirees behave similarly to the lowest income household, but the mechanism is slightly different. A substantial share of retirees do not save at all as they face the possibility of dying next period. In the subset of those who do save, the response is again strongest for those with low assets.

The average relative response within earnings profiles and asset percentiles is shown in figure 9. On average, the response is highest for middle income households and those with median asset holdings. Considering however only those who already save, the effect becomes significantly more pronounced for both low income households and retirees. The share of savers in those groups is 60.5% and 73.9%, respectively. Whether or not the response is conditional on savings matters particularly for agents with low asset holdings: At the 10th

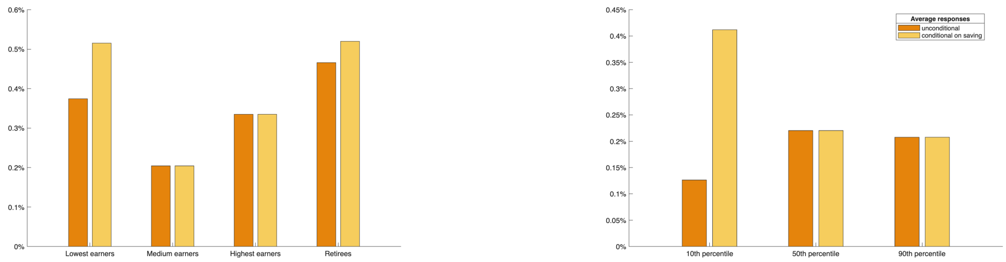
[13] The MPS is bounded above by a constant less than 1. A theoretical argument can be found in Ma and Toda (2021).



(a) MPS

(b) $\mathcal{D}$

Figure 8: Variation in key determinants of the consumption response across the income and asset distribution.



(a) within earnings states

(b) within wealth percentile

Figure 9: Average relative responses. The lighter bar shows the responses conditional on savings.

percentile, consumption is on average decreased by 0.6%, but by 3.2% in the group of savers. At the higher percentiles, everybody saves, so that there is no effect from conditioning.

A non-zero response to a perturbation dp_t at longer horizons is only observed if an agent does not expect to hit the borrowing constraint before then, i.e. if the product from 0 to t over marginal propensities to save is positive. Figure 10 shows the cumulative effect of dp_t for $t = 1, \dots, 51$ for an agent at the 60th percentile of their respective idiosyncratic group. Low income agents barely respond to perturbations in probabilities which are more than 5 periods out. In the unlikely cases in which they do not hit the borrowing constraint until then, they are better off overall. Not only is $\mathcal{D}$ in those cases lower, they also put little weight on them under the risk adjusted measure as the marginal utility is low. On the other hand, the cumulative response for high income agents continues to rise. They have a higher probability of saving in each period. Furthermore, on a long horizon and abstracting from the possibility of death, their personal probability distribution over idiosyncratic income states converges to the unconditional distribution. In particular, they account for low income states and additionally weigh them higher due to the risk adjusted measure.

The exposition in figure 10 assumes that the probability perturbation is equal in each period. In the full model of section 4, the probability rises more in the future, capturing worsening of climate change over time. This dynamic variation increases the response of high relative to low income agents. Finally, while this section focuses on the reaction in period 0, the perturbation in probabilities of course also affects future savings choices in an analogous manner. As asset holdings are a stock variable, these responses accumulate over time.

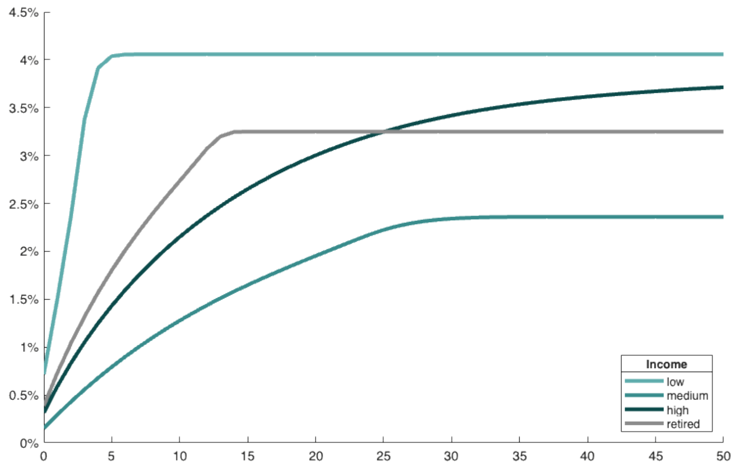


Figure 10: Cumulative relative response $-d\ln c_0$ of agents at the 60th percentile to equal perturbations dp_t over the horizon $t = 1, \ldots, 51$.

B Computational details

B.1. Details and robustness on PLM

This section provides additional details on the baseline forecasting rule, the non-stationary PLM, and compares the outcomes with alternative specifications of adaptive expectations.

B.1.1. Estimation procedure and mathematical details

This section provides details on the estimation procedure as well as some background information on the mathematics of dynamical systems to argue for the choice in algorithm.

For the discussion of underlying mathematical concepts within this section, let us think of the dynamic equilibrium as the solution to a known stochastic dynamical system, i.e.

$$\Psi_{t+1} = \mathcal{G}(\Psi_t, \zeta_t, T_t). \tag{B.1}$$

Stability A stochastic dynamic system is inherently unstable, but there are several, slightly distinct concepts which can be useful to understanding system characteristics. As the aggregate system is stochastic due to productivity shocks, there is no stationary cross-sectional distribution.

Due to the randomness in ζ, the system in (B.1) will not generally converge over time. For a stationary process however, as the mean of ζ is not time-dependent, a set of interest is given by the states to which the system converges if the noise term was at its mean value, i.e. if $\zeta_t = \overline{\zeta}$. In economics, this idea has been popularized under the name stochastic (or risky) steady state (SSS). The different term is helpful in reminding us of the subtle distinction when thinking about economic systems: to derive the individual choice functions which implicitly pin down the function $\mathcal{G}$, an economic modeler has to make an assumption on how forward-looking agents think of the process ζ. The SSS is usually understood to be the deterministic limit of the system driven by correct beliefs, see Coeurdacier et al. (2011) as the key reference. This standard interpretation can be helpful in understanding both the initial state of the economy of this paper, i.e. before the transition takes place, and the long run outcomes in the shifted system, with the implied capital values denoted within the paper by K_0^{SSS} and K_{CC}^{SSS} respectively. A deterministic version of the non-stationary shift can now be considered by initializing in the economy in the pre-transition SSS and then tracing out the time path implied by mean shocks along the transition, $\zeta_t = \overline{\zeta}_t$.

Importantly, it is not generally the case that the stochastic steady state coincides with the long run mean as $\mathcal{G}$ depends on ζ non-linearly. The long run mean of a stationary system is an alternative obvious concept to consider as a potential point of interest. Even for millions of observations, however, the sequence of the long run mean fails to become Cauchy. Convergence occurs much faster under stratified samples, discussed in more detail below, which I thus use to approximate a long run mean.

Note that I do not provide any theoretical arguments for the existence of these limits. The analytical discussion here purely serves as background on the concepts, while the used values are based only on numerical simulations.

Model selection The orginal paper by Krusell and Smith (1998) shows that a first order difference equation can well approximate the law of motion of capital for a given aggregate state[14]. When introducing an additional state variable into the model, it seems reasonable to, as a first try, include this variable in the approximation of the law of motion, which is precisely what I do by estimating parameters (a, b, c, d, e) to fit the model

$$\log(K^+) = a + b \cdot \mathbb{1}_{\zeta=\zeta^L} + (c + d \cdot \mathbb{1}_{\zeta=\zeta^L}) \log(K) + e \cdot T.$$

As illustrated below, this law of motion performs well in forecasting future capital. To further validate my approach, I additionally explore the gains from introducing non-stationarity in alternative, more general ways. Specifically, I consider a model

$$\log(K^+) = a_T + b_T \cdot \mathbb{1}_{\zeta=\zeta^L} + (c_T + d_T \cdot \mathbb{1}_{\zeta=\zeta^L}) \log(K)$$

in which the parameters (a_T, b_T, c_T, d_T) are linear or quadratic functions in T[15].

Initial histogram As the non-stationary nature of my problem prohibits discarding an initial interval of simulations, a sensible guess for the initial histogram is crucial. To validate the converged coefficients, I run one final step of the algorithm starting with the resulting asset distribution.

Stratified sampling Understanding the key underlying dynamics of the non-stationary model requires the use of cross-sectional, rather than dynamic, simulations. At the same time, the shift in temperature is slow, and there is no a-priori estimate in how long the stochastic economic impacts take to behave approximately stationary. Thus, a naive solution approach

[14]Under the common assumption of CRRA utility, the implied consumption function is close to linear in assets except close to the borrowing constraint. As asset-poor agents contribute a negligible amount to overall capital, the asset choice approximately aggregates, so that the mean of capital performs well as sufficient statistic.

[15]The baseline approach can be seen as a specific case where a_T is linear in T and all other parameters are independent of T.

requires large numbers of both dynamic and cross-sectional simulations, quickly making the iteration on model parameters needed for estimation of the PLM infeasible.

In my baseline implementation, I use $T_{sim} = 200$ time steps. For this timespan, there are $2^{200} \approx 10^{60}$ possible paths for the process $\{\zeta_t\}_t$. This section explains a method to stratify the cross-sectional draws, a key trick which makes the algorithm computationally feasible, and under which a comparatively small number of simulation $n_{sim} = 1000$ leads to numerical convergence.

Random draws from a smaller cross-sectional sample however may lead to large deviations of the ζ^L share across the number of draws from p_t. For each period t, I fix the number of draws that are in the low state as the closest integer $\tilde{n}_t^L$ to $p_t \cdot n_{sim}$. The vector of realized values in period t is then taken to be a random perturbation of the vector of size n_{sim} which has $\tilde{n}_t^L$ entries equal to ζ^L and $n_{sim} - \tilde{n}_t^L$ entries equal to ζ^H.

The resulting simulation sample matches the share of low states within a period by design extremely well, which is in contrast to a completely randomized sample. Figure shows the time variation of per-period means for randomized samples of different sizes in comparison to a stratified sample of size $n_{sim} = 1000$.

Crucially, the stratified sample is able to match accurately the variance both in the process ζ and in the endogenous outcome K. To understand why, note that the stratification does not exclude any realizations $\{\zeta_t\}_t$. It only affects the probability of a specific draw conditional on the other draws considered in the simulation.

As the algorithm to find the baseline PLM iterates on simulated dynamic equilibria, the stratification is a necessary step in reducing the computational complexity, so that the model can be solved on a standard laptop. While the cost of increasing the sample is less costly for simulations of dynamic equilibria, the gains from stratification still reduce run times, so that I use the procedure for all simulations.

B.1.2. Performance

The non-stationary PLM used by agents with $\pi > 0$ is based on a heuristic algorithm, without theoretical results guaranteeing a good fit to realizes values. While the definition of the dynamic equilibrium 2 does not require forecasted capital to match well the realized time path, this section demonstrates that the forecast performs actually quite well.

Figure 11 shows the average forecast error over time in simulations for a range of different initial values of homogeneous beliefs π. The value π is further assumed to be the accurate belief. Across all values, the PLM $\mathcal{H}_\pi$ performs well, with average errors of magnitude 10^{-4}. This is one magnitude larger than the convergence bound on the estimated PLMs, $\mathcal{H}_0$ and $\mathcal{H}_1$.

B.1.3. Comparison to alternative PLMs

This section compares the converged non-stationary PLM with two alternative forecasting rules, the stationary one used by agents who do not belive in the non-stationary shift and the naive one under which capital is simply assumed to be the same as before. This comparison is helpful to understand the results on PLM dependence of individual choices, discussed in

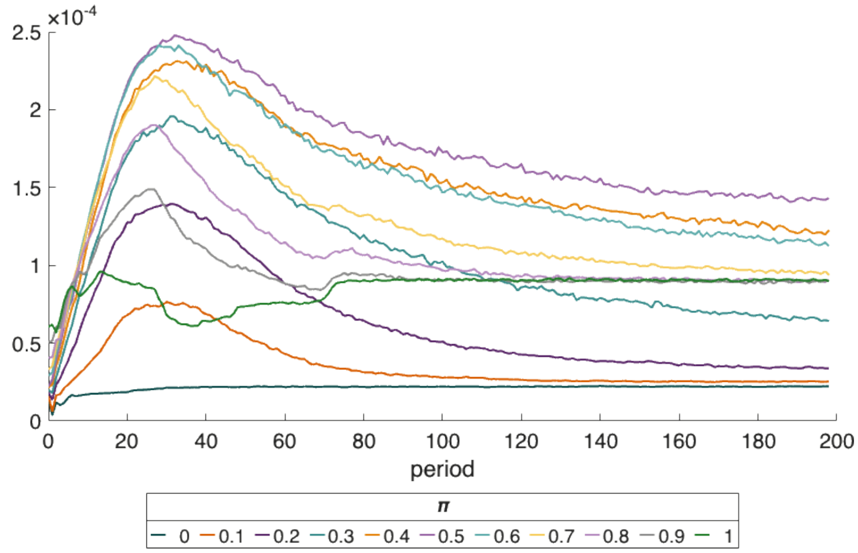
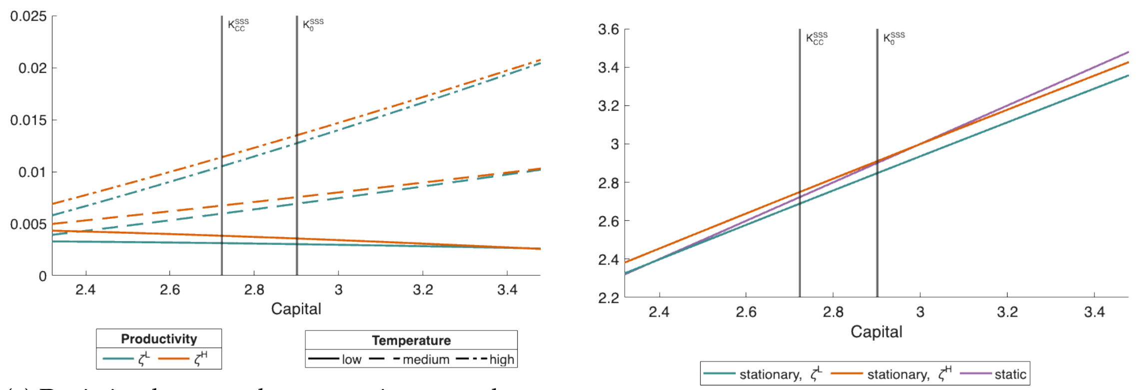


Figure 11: Relative error in one-period capital forecast under accurate beliefs



(a) Deviation between the non-stationary and stationary PLM

(b) Stationary PLM compared to static expectations

Figure 12: Comparison between PLMs

section **??**.

Figure 12a shos the absolute differences in forecast under the non-stationary PLM $\mathcal{H}_1$ and the stationary PLM $\mathcal{H}_0$. We first notice that, for a given productivity state and across all temperature levels, the non-stationary forecast predicts a higher level of capital in the next period. Note however that, for values further in the future, beliefs over the aggregate productivity process are also relevant for the capital forecast. As capital accumulation is lower in the low productivity state, this pushes down the forecast of a more concerned agent.

Figure 12b compares the forecasted capital between the stationary PLM and naive, static expectations. Under the latter, the current productivity state ζ is irrelevant for next period's forecast. The figure shows that naive expectations lie between the forecasts under the two productivity shocks for the most relevant part of the capital grid. In particular for the low state ζ^L however, naive expectations predict a considerably higher capital stock, thereby underestimating the persistent economic impacts of adverse shocks.

B.2. Algorithm for updated forecasting rule

To introduce the adaptive algorithm, let $\{\zeta_t\}$ be some fixed draw of productivity shocks. Let $\mathcal{H}_0^{adp}(K, \zeta, T)$ be some initial guess for the perceived law of motion. In my implementation, I take this to be the static PLM of the type $\pi = 0$ and drop the explicit dependence on T, as temperature increase is fully pinned down by time. We assume the same fixed functional form as before and abstract from dependency on the belief π, as everyone observes and learns from the same aggregate states. Let Θ denote the set of coefficients, so that

$$\mathcal{H}_0^{adp}(K, \zeta) = \mathcal{F}(K, \zeta; \Theta_0).$$

Further, let Σ_0 denote the covariance matrix obtained from the initial regression. Fix some $s > 0$, which will be the interval over which agents do not change their PLM. They update at points $\{t_s^* = ts \mid t \geq 0\}$, so that $\mathcal{H}_{t_s^*}^{adp} = \mathcal{H}_{t_s^*+i}^{adp}$ for all $i = 0...s-1$.

At any t_s^* for $s > 0$, we want to update the coefficients and use them to solve for new choice functions. An important modeling choice here is how much weight to put on new observations versus old previous estimates, usually interpreted as a type of finite memory. In the present setting, this weight also determines how much agents account for the non-stationarity in the capital process.

Assuming a fully rational and stationary updating rule, the updated coefficients can be found recursively by combining a prior guess and the new data $\mathbf{Y}_s = (\log(K_{t+1}))_{t=t_s^*+i}$ and

$$\mathbf{X}_s = (1,\ \log(K_t),\ \mathbb{1}_{\zeta_t=\zeta^L},\ \mathbb{1}_{\zeta_t=\zeta^L} \cdot \log(K))_{t=t_s^*+i}.$$

Assume Θ_{s-1} is the best linear approximation given all previous data $(\mathbf{X}_{-s}, \mathbf{Y}_{-s})$ and $\Sigma_{s-1}$is the corresponding covariance matrix. The covariance matrix on the entire dataset then satisfies the recursion

$$\Sigma_s = \mathbf{X}_s^\top \mathbf{X}_s + \mathbf{X}_{-s}^\top \mathbf{X}_{-s} = \mathbf{X}_s^\top \mathbf{X}_s + \Sigma_{s-1}.$$

Using the identity $\Theta_{s-1} = \Sigma_{s-1}^{-1}\left(\mathbf{X}_{-s}^\top \mathbf{Y}_{-s}\right)$ for the previous OLS estimator, the updated estimator on all data can now be expressed as

$$\begin{aligned}
\Theta_s &= \Sigma_s^{-1}\left[\mathbf{X}_{-s}^\top \mathbf{Y}_{-s} + \mathbf{X}_s^\top \mathbf{Y}_s\right] \\
&= \Sigma_s^{-1}\left[\left(\Sigma_s - \mathbf{X}_s^\top \mathbf{X}_s\right)\Theta_{s-1} + \mathbf{X}_s^\top \mathbf{Y}_s\right] \\
&= \Theta_{s-1} + \Sigma_s^{-1}\mathbf{X}_s^\top\left[\mathbf{Y}_s - \mathbf{X}_s \Theta_{s-1}\right].
\end{aligned}$$

In particular, it suffices to carry the estimate Θ_{s-1} and the 4×4 dimensional covariance matrix Σ_{s-1} for this updating procedure.

I introduce memory dependence by instead estimating a new estimate $\tilde{\Theta}_s$ on the data $(\mathbf{X}_s, \mathbf{Y}_s)$ and using a simple weighted average

$$\Theta_s = \lambda\Theta_{s-1} + (1-\lambda)\tilde{\Theta}_s$$

as the new guess. Note that it is $(\mathbf{X}_s)^\top \mathbf{X}_s$ may fail to be of full rank over a (short) finite sample of length s; in those cases, I only update those entries of Θ_s over which new information has become available.

B.3. Solution of dynamic equilibria

Given a perceived law of motion for capital and an initial distribution, the implied dynamic equilibrium can be easily computed using standard methods. This section discusses the choice of the initial distribution and the exact implementation of my model. All codes are written in Matlab.

B.3.1. Initial cross-sectional distribution

The cross-sectional distribution is three-dimensional, over demographic states ϕ, asset holdings a, and beliefs π. In a dynamic model, the distributions over demographics and wealth become mechanically correlated, as higher income individuals save more. To eliminate this well-understood mechanism from my analysis, I initialize the dynamic equilibrium in the no-climate change SSS. Capital holdings in the SSS are slightly lower than in the long run mean, but this deviation has negligible impacts for dynamic outcomes.

In the baseline version, I assume prior beliefs to be initially independent of income and wealth. Over time, higher concern endogenously leads to increased asset holdings, due to the key savings channel which I want to isolate. In the panel data, climate concern is slightly correlated with education and income, but the relationship with income becomes insignificant when controlling for education. It is straightforward to allow for a positive covariance between the demographic state and beliefs in simulations.

Initial beliefs At time 0, I assume every agent in the economy draws a prior belief π.

To pin down the initial distribution, I implement both parametric and non-parametric approaches. An important choice in a setting with learning is whether or not to include people with $\pi \in \{0, 1\}$, as these agents without uncertainty do not learn over time.

A parametric approach is helpful to vary the concern mean and variance separately. The standard continuous parametrization of a distribution over $[0, 1]$ is the Beta distribution, which is fully identified by the mean μ_Π and variance Σ_Π. Importantly, the variance of a Beta distribution is constrained by $\mu_\Pi \cdot (1 - \mu_\Pi$. As with any continuous parametrization, the mass of agents with a specific belief will always be zero; in particular, this holds for the extreme beliefs $0, 1$. In the baseline, I discretize using nodes within $(0, 1)$, so that all agents are somewhat uncertain.

In an extension, I introduce extreme beliefs by fixing the shares s_0 and s_1 of agents with $\pi = 0$ and 1, respectively, and then fit a Beta distribution on $(0, 1)$. When fixing overall mean and variance, the parameters for the inner Beta distribution are pinned down by

$$\mu_{\Pi,B} = \frac{\mu_\Pi - s_1}{1 - s_0 - s_1}, \quad \Sigma_{\Pi,B} = \frac{\Sigma_\Pi - s_1 + \mu_\Pi^2}{1 - s_0 - s_1} - \mu_{\Pi,B}^2.$$

The non-parametric approach simply imposes some histogram on initial beliefs.

Please select whether, on the whole, you personally believe or do not believe each of the following statements.

Response options are: yes (1), no (2)

Statement	Variable name
People in the UK will be affected by climate change in the next 30 years.	scopecl30
People in the UK will be affected by climate change in the next 200 years	scopecl200

Table 11: Beliefs about extent of climate change, asked in waves 4 and 10

B.3.2. Solving the consumer problem

For a given PLM $\mathcal{H}$, the consumer choice can be directly computed at each point in the grid. I solve for maximizing asset choice a' directly using the endogenous grid method suggested by Carroll (2006). This avoids solving maximization problem in each period, significantly simplifying computation. I iterate until the convergence error is $< 10^{-6}$.

The computation is further sped up significantly by vectorization.

B.3.3. Computing time paths

Given the choice function a', the definition of a dynamic equilibrium pins down all variables in the economy for a given sequence $\{\zeta_t\}$. In practice, however, the choice function is only defined on a discrete grid, thus requiring interpolation both within the cross-section and on the aggregate variables. For the former, I follow the endogenous gridpoint method for distributional dynamics suggested by Bayer et al. (2024) which generalizes the histogram method of Young (2010). To ensure shape preservation, in particular monotonicity, I alter their method slightly by using piecewise cubic Hermite interpolation instead of splines.

The simulation of draws can easily be parallelized. This speed improvement is necessary for the implementation of an updated forecasting rule, where the choice function has to be solved repeatedly.

C UK Understanding Society: data and additional analysis

C.1. Survey questions

Tables 11 and 12 report all questions which are related to climate change concern.

Tables 13 - 17 report the precise questions and response modalities for the variables concerning environmental habits (table 13), beliefs and attitudes (tables 14 - 15) and savings (table 17).

Table **??** reports descriptive statistics on the responses on savings. From wave 4 to wave 10, both the share of respondents stating that they save and the average amount of savings per month increased.

Table 17 reports the additional savings related question, asking about long term vs short

Please select the extent to which you agree or disagree with the following statements.

Response options are: strongly agree (1), tend to agree (2), neither agree nor disagree (3), tend to disagree (4), strongly disagree (5)

Statement	Variable name
If things continue on their current course, we will soon experience a major environmental disaster.	meds
The so-called ’environmental crisis’ facing humanity has been greatly exaggerated.	crex
The effects of climate change are too far in the future to really worry me.	nowo

Table 12: Beliefs concerning climate change, asked in waves 4 and 10

Now a few questions about the environment.

Could you tell me how often you personally do each of the following things.

Response options are: always (1), very often (2), quite often(3), not very often (4), never (5)

Habit	Variable name
Leave your TV on standby for the night	envhabit1
Switch off lights in rooms that aren’t being used	envhabit2
Keep the tap running while you brush your teeth	envhabit3
Put more clothes on when you feel cold rather than putting the heating on or turning it up	envhabit4
Decide not to buy something because you feel it has too much packaging	envhabit5
Buy recycled paper products such as toilet paper or tissues	envhabit6
Take your own shopping bag when shopping	envhabit7
Use public transport (e.g. bus, train) rather than travel by car	envhabit8
Walk or cycle for short journeys less than 2 or 3 miles	envhabit9
Car share with others who need to make a similar journey	envhabit10
Take fewer flights when possible	envhabit11

Table 13: Questions about environmental habits in waves 4 and 10

Question	Variable name	Response options
Which of these best describes how you feel about your current lifestyle and the environment?	ftst	happy with what I do (1), like to do a bit more (2), like to do lots more (3)
Which of these would you say best describes your current lifestyle?	crlf	I don't really do anything (1), do one or two things (2), do quite a few things (3) that are environmentally-friendly, I'm environmentally friendly in most things (4), everything (5) I do
Do you agree or disagree that being green is an alternative lifestyle, it's not for the majority?	grn	agree strongly (1), agree (2), disagree (3), disagree strongly (4)

Table 14: Opinions about personal lifestyle in relation to the environment, asked in waves 4 and 10

Please select the extent to which you agree or disagree with the following statements.
Response options are: strongly agree (1), tend to agree (2), neither agree nor disagree (3), tend to disagree (4), strongly disagree (5)

Statement	Variable name
My behavior and everyday lifestyle contribute to climate change.	bccc
I would be prepared to pay more for environmentally-friendly products.	pmep
Climate change is beyond control - it's too late to do anything about it.	tlat
Any changes I make to help the environment need to fit in with my lifestyle.	fitl
It's not worth me doing things to help the environment if others don't do the same.	noot
It's not worth the UK trying to combat climate change, because other countries will just cancel out what we do.	canc

Table 15: Beliefs concerning climate change, asked in waves 4 and 10

Statement	Response options
Do you save any amount of your income, for example by putting something away now and then in a bank, building society, or Post Office account, other than to meet regular bills? Please include share purchase schemes and ISA's.	Yes (1), No (2)
About how much on average do you personally manage to save a month?	numerical value

Table 16: Questions about savings, asked in even waves

Statement	Response options
Would you say your savings are mainly long term savings for the future or mainly short term savings for things you need now and for unexpected events?	Mainly long term (1), mainly short term (2), both equally (3), neither (4)

Table 17: Question about long term and short term savings

	fitl	noot	pmep
fitl	1		
noot	0.321	1	
pmep	0.140	0.218	1

Table 18: Correlations between indicator variables for ι^{resp}

term savings.

To evaluate the responses for the question on long-term vs short-term savings, I create dummies on what they indicated, with those that responded *Both equally* being put in both groups.

C.2. Construction of additional indices

A second index, ι^{resp}, aims to measure how much the participant believes that they have an individual responsibility and scope to mitigate climate change. In the baseline specification, this index is calculated based on the degree to which participants agree or disagree with the statements *It's not worth me doing things to help the environment if others don't do the same* (noot), *I would be prepared to pay more for environmentally-friendly products* (pmep) and *Any changes I make to help the environment need to fit in with my lifestyle* (fitl). Again, the indicators are realigned and normalized, and a higher value means a higher belief that individual action can mitigate climate change. Table 18 shows the correlations of the different indicators after being realigned and normalized.

The two indices are positively correlated with a correlation coefficent of

$$\rho_\iota = 0.463.$$

It is plausible that people are worried about the climate but do not consider themselves able to do anything about it, i.e. having a high value for ι^{conc} but a low value for ι^{resp}. It is more surprising to see that there are some people who report a high degree of assuming personal responsibility, but lower concern for the climate. These may be people who are concerned about the environment rather than the climate, or people who believe that the global climate is changing due to anthropogenic emissions, but without a large impact on themselves and the UK.

The questions about an individual's environmental habits can broadly be separated into two classes: One accounting for environmentally friendly behavior in the household, e.g.

	Wave 4	Wave 10	Total
ι^{conc}	0.669	0.740	0.701
	(0.199)	(0.191)	(0.199)
ι^{resp}	0.507	0.557	0.530
	(0.173)	(0.173)	(0.175)
η^{hh}	0.539	0.572	0.554
	(0.168)	(0.154)	(0.163)
η^{transp}	0.226	0.263	0.243
	(0.182)	(0.204)	(0.193)

Table 19: Descriptive statistics for indices. Means with standard deviations in brackets

	ι^{conc}	ι^{resp}	η^{hh}	η^{transp}
ι^{conc}	1			
ι^{resp}	0.464	1		
η^{hh}	0.215	0.263	1	
η^{transp}	0.120	0.145	0.226	1

Table 20: Correlations between indicator variables for ι^{resp}

saving energy around the house and reducing packaging, and one describing habits concerning transportation, e.g. using car sharing platforms or avoiding flying when possible. The participants are asked how often they take certain actions and respond on a five step scale ranging from *Always* to *Never*. As for ι^{conc} and ι^{resp}, the indicators are normalized to lie between 0 and 1 and realigned such that higher numbers reflect enganging in an environmental habit more often. They are then aggregated into two indices representing the two classes, η^{hh} for habits in the household and η^{transp} for habits related to transportation.

Table 19 displays means and standard deviations for each of the indices. The means of all of the indices increased from wave 4 to wave 10, indicating that people became more aware about climate change, more conscious about their own contribution and also engaged in environmental habits more often. Table 20 shows the pairwise correlations of all four indices with each other. In particular, note that both habits indices are slightly more correlated with ι^{resp} than with ι^{conc}.

D Novel Survey: details and additional analysis

This section provides additional details about the specific survey questionnaire.

	$\Delta s > 0$	$\Delta s < 0$	$\Delta s = 0$
Δs	0.4558***	-0.2806***	
	(0.0459)	(0.0186)	
Observations	160	106	277

$^{*}p$ <0.1; $^{**}p$ <0.05; $^{***}p$ <0.01

Table 21: Direction of savings response and averages within sub samples.

D.1. Sample selection and power analysis

To estimate the number of participants needed within the survey, I use a power analysis based on the pilot data and the results from section 3. I want to find the necessary number of participants to have an β% chance of detecting an effect of size d as statistically significant on the level α using a t-test. I use standard values of $\beta = 0.8$ and $\alpha = 0.05$. For a estimated effect size $d = \overline{x}/SD_x$, I thus need a sample size of

$$n = \left(\frac{Z_{1-\alpha/2} + Z_{1-\beta}}{d} \right)^2 = \left(\frac{2.8}{d} \right)^2 .$$

In the pilot study, the effect size is at $d = 0.0696$, requiring a sample of 1600 participants. The effect sizes in section 3 however are substantially larger, with the baseline result at $d \approx 0.29$, under which 100 participants would be enough.

For the main study, I initially aim to recruit 600 participants. The power is sufficient, as shown by the analysis in 3.2.4. As a significant share of respondents does either not confirm their age or withdraws consent, their spots are opened again a few days later. To avoid any confounding factors, I include the pilot and late participants only in robustness checks.

D.2. Additional analysis

Looking more deeply into the responses instead of only focusing on averages, we see strong heterogeneity in the direction of the response which is concealed by the aggregate effect. Within the final sample of 543 respondents, only 160 actually increase their savings; 277 do not adjust their decisions, and 106 actually decrease their savings choice. Table 21 repeats the analysis on the subsamples of those who increase and decrease their choice, respectively. In both cases, the response is significant, but the increase is on average higher than the decrease, showing that the average effect in table 5 is not only due to the larger number of increasers.

This heterogeneity is an important finding as it contradicts the theoretical prediction from the model of section 2. There are several possible economic explanations for this finding. First, remember that the result in section 2 was based on the assumption of CRRA utility with $IES < 1$, under which income effects dominate, an assumption that may not hold true in the cross-section. Furthermore, the survey design specifically avoids fixing exact expectations of **how** climate change impacts will materialize in the UK. The theoretical model on the other hand considers one specific type of climate impacts, as shocks to productivity. The questionnaire on which mechanisms respondents expect to matter for the UK gives additional insights into how they think about climate change, and how this correlates with differences in savings responses.

D.3. Full instructions

Figures 13-15 show the exact instructions of the survey. The survey was designed with and hosted on the platform Qualtrics.

Participants who do not tick both boxes on the welcome screen are immediately moved out. If participants do not pass the attention check at their first attempt, they are presented with the same attention check again. This is due to Prolific guidelines which do not allow rejecting participants of a survey taking more than 5 minutes based on a single attention check. There is a small number of responses who initially do not pass the attention check, who are taken out of the main analysis.

There are two points of randomization: first, which savings choice block is presented first, and secod, which order the mechanisms of climate impacts are presented. On the final questionnaire, the question on what percentage they save is voluntary and only shown if already indicated that they save.

This slider icons shown in figure 14 are not fully accurate; in the actual survey, the slider starts at zero. It has to be moved once to register a response. As participants move the slider, they see the amount they are currently indicating to sav on the side.

Start of Block: Welcome

Welcome!
General Information: The aim of this research is to understand individual savings decisions under different hypothetical scenarios. We appreciate your interest in participating in this survey. Please read through this information before agreeing to participate (if you wish to) by ticking the box below. You may ask any questions before deciding to take part by contacting the researcher. The lead researcher is Hannah Römer, who is attached to the Department of Economics at the University of Oxford. This research is being completed under the supervision of Alexandre Kohlhas. No background knowledge is required. There are no right or wrong answers, we are simply interested in your preferences and beliefs. The survey should take about 6 minutes. Your data will only be accessible to the researchers listed above.
Do I have to take part? No. Please note that participation is voluntary. If you do decide to take part, you may withdraw at any point for any reason before submitting your answers by closing the browser. However, we are only able to reimburse participants who complete the full survey.
How will my data be used? Your answers will be completely anonymous, and we will take all reasonable measures to ensure that data remain confidential. We need to collect your Prolific ID to be able to pay you. If available, we obtain the following data from your Prolific account that could identify you: age, sex, highest education level completed, personal income, household income, nationality and ethnicity. Your IP address will not be stored. The responses you provide will be stored in a password-protected electronic file on University of Oxford secure servers and may be used in academic publications, conference presentations and a doctoral dissertation. Identifiable information will be deleted as soon as it is no longer required for the research. Research data will be stored for a minimum of 3 years after publication or public release of the work of the research.
Who will have access to my data? The University of Oxford is the data controller with respect to your personal data and, as such, will determine how your personal data is used in the research. The University will process your personal data for the purpose of the research outlined above. Research is a task that we perform in the public interest. Further information about your rights with respect to your personal data is available from https://compliance.admin.ox.ac.uk/individual-rights. We would also like your permission to use the de-identified data in future studies, and to share data with other researchers (e.g. in online databases).
Who has reviewed this research? This research has received favourable opinion from a subcommittee of the University of Oxford Central University Research Ethics Committee [Reference: Economics (Econ) DREC - 2189366].
Who do I contact if I have a concern or I wish to complain? If you have a concern about any aspect of this research, please contact Hannah Römer (hannah.roemer@economics.ox.ac.uk), who will try to answer your query. We will acknowledge your concern within 10 working days and give you an indication of how it will be dealt with. If you remain unhappy or wish to make a formal complaint, please contact the Economics Ethics Officers (ethics@economics.ox.ac.uk).
Please note that you may only participate in this survey if you are 18 years of age or over. If you have read the information above and agree to participate with the understanding that the data (including any personal data) you submit will be processed accordingly, please tick both boxes below to start.

- ☐ Yes, I agree to take part (5)
- ☐ I certify that I am 18 years of age or over (6)

Please enter your Prolific ID. ____

Start of Block: Attention check

The next question is about the following problem. In questionnaires like ours, sometimes there are participants who do not carefully read the questions and just quickly click through the survey. This compromises the results of research studies. **To show that you are reading the survey carefully, please choose both "Very strongly interested" and "Not at all interested" as your answer to the next question.** Given the above, how interested are you in politics?

- ☐ Very strongly interested (1)
- ☐ Very interested (2)
- ☐ A little bit interested (3)
- ☐ Not very interested (4)
- ☐ Not at all interested (5)

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Figure 13: Welcome page and attention check (on a new page).

Start of Block: Savings choice - Intro

Consider a hypothetical situation in which you **unexpectedly** receive **a one-time payment of 5000 GBP** today. This payment is unconditional. We want to know how much of this money you would save, taking a specific scenario for granted. Any money which you do not save is assumed to be spent. Below, we provide a brief description of what we mean by saving and spending. Please read it carefully, and then tick the box below.

Saving means that, instead of using money today, you reserve it for future use. Examples of savings include cash reserves, money in bank accounts, retirement accounts, financial assets or real estate. Repaying debt is also an important form of saving. By repaying debt today, you owe less money in the future, which means that more money is available for future use.

Spending includes all money spent on goods and services, including rent. Goods include durable goods (such as electronics, furniture, or car maintenance) and nondurable goods (such as groceries, vacations, or gasoline).

- o Okay, I understand. (4)

You will now be presented with different scenarios about long run trends. Please take the scenarios as given when indicating your savings choice, no matter how likely you think these scenarios are.

Start of Block: Savings Choice - change

Scenario: Assume that currently, climate-related events with significant negative consequences to the UK happen on average once every 7 years, and that the average frequency **increases** due to climate change. Assume that these events will happen, on average, twice as often by 2040 (once every 3.5 years) and more than three times as often by 2100 (once every other year).

Please use the slider to indicate how much of the hypothetical one-time payment of 5000 GBP you would choose to save under this scenario.

If you wish to indicate a value of 0, you need to move the slider once and then back to register your response. You can choose increments of 250 GBP.

	spend all save all
GBP	

Start of Block: Savings Choice - constant

Scenario: Assume that currently, climate-related events with significant negative consequences to the UK happen on average once every 7 years, and that the average frequency **will not change until 2100.**

Please use the slider to indicate how much of the hypothetical one-time payment of 5000 pounds you would choose to save under this scenario.

If you wish to indicate a value of 0, you need to move the slider once and then back to register your response. You can choose increments of 250 pounds.

	spend all save all
GBP	

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Figure 14: Savings Choice. The two blocks ′change′ and ′constant′ were presented in random order.

Start of Block: Mechanisms

Do you think climate change will affect the UK, and if yes, how? Please select all that apply out of the options below.

- ☐ Increased flood risk (15)
- ☐ Impacts on human health, e.g. due to heatwaves, worsening air quality or increased risks of pandemics (16)
- ☐ Adverse effects on food supply and agriculture, e.g. due to crop losses (17)
- ☐ Positive effects on agriculture, e.g. due to the possibility to grow additional crops domestically (18)
- ☐ Disruptions to the global economy and supply chains (19)
- ☐ Biodiversity loss (20)
- ☐ Migration (21)
- ☐ Global conflicts (22)
- ☐ Disruption of infrastructure, e.g. due to higher frequency of environmental disasters (23)
- ☐ Cooler temperatures due to a changing Gulf Stream (24)
- ☐ Other (25)
- ☐ I do not believe that climate change will affect the UK. (26)

Start of Block: Questionnaire

Do you currently save any amount of your income?

- o Yes (1)
- o No (2)

Only show if previous answer Yes:
What percentage of your annual income do you save?

Please enter a number between 0 and 100 (1)

____

Do you believe that climate change already has or will have **significant adverse effects** on the **aggregate UK economy**?

- o Yes (1)
- o No (2)

Negative impacts to the aggregate economy could have indirect effects on you. For example, they may affect average wages, interest rates or the unemployment rate. On the other hand, direct impacts on you personally, such as flood damage to your house, may not matter for the aggregate economy.
Do you think that climate change already has or will have **significant** adverse effects **on you personally**?

- o Yes, both direct and indirect effects (1)
- o Yes, but only indirect effects (2)
- o Yes, but only direct effects (3)
- o No (4)

Have you so far experienced any **financial losses** that you believe can be attributed to climate change? Examples may include flood damage to your house, higher prices of agricultural goods, or lower ability to work during a heatwave.

- o Yes (1)
- o No (2)

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Figure 15: Questionnaire. The options in the 'mechanisms' block were presented in random order, except for the final response for no impacts. If the final option was selected, participants could not select another one.